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A NATIONAL SHEEP POLICY

W. H. J. TISDALE

Canadian Co-operative Wool Growers Limited, Toronto

It is with a great deal of diffidence that I attempt to present to the Canadian Society of Animal Production this special paper by way of opening up a discussion on a subject that is entitled to much more thought and consideration than I have been able to give to it. Moreover, I am extremely sorry that a business trip into Western Canada at this season of the year makes it impossible for me to sit in with those members of the Society who are so vitally interested in seeing the sheep industry of this country develop into something infinitely bigger and better than has been the case thus far.

During the past twenty years or so that I have been actively associated with sheep interests in this country—first in Eastern Canada, then in the West, and more recently in a Dominion-wide way as an executive of the Canadian Co-operative Wool Growers, Limited, the thing that has impressed me most of all is that in a country like Canada where ample development is possible, we seem to make absolutely no progress whatever towards a larger sheep population. I have heard various reasons advanced in explanation of this, some going so far as to say that our climatic and feed conditions do not warrant increased sheep production, a reason that to me is entirely beside the mark when the scope of the country is taken into consideration, and one realizes the variety that is available from the valleys and grazing plateaux of British Columbia to the foothills of the Rockies and the great plains area of Western Canada, on through to the farm conditions existing in these Eastern Provinces.

We need only to analyze the sheep industry as it has developed in other countries, more notably those five countries which today produce about 90% of the world's wool suitable for wearing apparel or similar purposes. These countries are Australia, the United States, South America, South Africa and New Zealand. Granting, of course, that some of these countries such as Australia and New Zealand are more admirably suited to the development that has taken place upon such a large scale, there still remains no reason to doubt that we could expand our operations in Canada. Australia produces the largest quantity of wool of any country, and the quality is high, with a large percentage being of the Merino type, the remainder being Crossbred. It is a continent similar in size to Canada, with a population of approximately 6,000,000 people, and it is today carrying well over 100,000,000 sheep—practically the same number as in her

[1] Assistant Manager.

[2] Paper read by L. C. McQuat before the annual meeting of the Canadian Society of Animal Production (Eastern Section), at the Ontario Agricultural College, June 12, 1935.

record year of 1891 when there were 106,000,000 sheep in Australia. The story of wool production, however, in Australia provides a most interesting study in that the record number of sheep in 1891 produced only an average of slightly more than 4½ pounds of wool per head, as compared with an average production of nearly 9 pounds per head today. Here, then, appears one of the unseen factors that means nothing to the men not conversant with the industry, and as one writer has put it—"If there are better sheep breeders than those on the Australian Stations I have never seen them. It is a science and a fine art with them. I studied their methods of perfection toward which they are constantly aiming. Each of their ewes is carefully examined with reference to the fineness and quality of her wool. She is then scheduled to be mated so as to correct any trend toward over-fineness or over-coarseness of wool in the next generation." This statement prompts me to comment in passing upon the indifferent hit-and-miss methods of breeding followed by our sheepmen so generally throughout Canada.

In New Zealand we find a smaller country, having over 25,000,000 sheep within its borders, or almost 250 sheep per square mile—about 1 sheep for each 2 acres of available pasture or tillable land.

South Africa has an area of some 473,000 square miles, and a sheep population of about 40,000,000 head—slightly over 84 sheep to the square mile.

In Canada, government statistics tell us that we have something better than 3,000,000 head of sheep, a figure which as nearly as I can determine has fluctuated very little over the past forty or fifty years.

Still more vital in a study of Canadian agriculture during the more recent and extremely difficult years is the fact that the sheep industry stands out as having produced results and sustained its operators where other phases of agriculture have failed. It is significant that the man engaged today in sheep raising in Canada has needed and has received less consideration in the form of direct relief than the wheat farmer or the cattle rancher. In fact, the sheep rancher seems to get by almost entirely on his own resources, even when the struggle is extremely difficult. Then, too, in the rehabilitation of agriculture such as is taking place in our Western Provinces today, sheep will find their place and fit into the scheme of things more quickly than will any other kind of live stock. Numerous examples might be cited of farmers who were unable to make a living by growing grain in certain drought areas that should perhaps never have been broken from the original prairie, but who today are self-supporting in the same district by utilizing abandoned farms for their sheep ranching operations.

Then, if there is any doubt about our Canadian climate being too varied and rigorous, about all one needs to do is to consider the Rainy River District of Northern Ontario where in the past six years a remarkable development has taken place in the industry and where sheep are today one of the mainstays of Rainy River agriculture.

The Province of British Columbia provides still further variety, an area sometimes described as a "sea of mountains," or again as a "land of valleys"; both types of topography are proving suitable to the rearing of sheep, with the valley lands for the production of winter feeds, and the

uplands or mountain plateaux providing tremendous areas for summer grazing.

All these observations and possibilities have led me to the conclusion that much time might profitably be devoted to the working out of a general scheme or National Policy for Canada. It is not the first time a suggestion of this nature has been made, as I recall four years ago this month, following a conference in Toronto of sheep farmers, ranchers, government officials, representatives of the packing industry, live stock marketing and wool marketing organizations, some concrete action was taken to place the situation as it existed at that time before the right authorities. The one outstanding result achieved as a result of that conference was the practical elimination of frozen lamb reaching the Canadian consumer from foreign countries, and the concentration upon our home-grown product. We were supposed to go further with certain other ideas put forward by that conference, and if I recall correctly there was urged upon the Dominion Department of Agriculture the appointment of a permanent National Sheep Committee. This Committee was to represent all interests and its appointment was suggested for the express purpose of further investigating the possibilities of the various ideas and wherever possible carrying them to fruition. So far, nothing of material moment has happend, and in saying this I do not wish for one minute to belittle the government policies already in effect and the very fine work being done by government officials, both provincial and federal, throughout the whole Dominion. These policies in general may be enumerated as follows:—

1. Federal Ram Club Policy in the Maritime Provinces.
2. Federal Ram Grading Policy in effect throughout Canada.
3. Federal Premium Policy on Rams.
4. Federal Wool Grading Policy.
5. Federal Lamb Feeding Projects.
6. Boys' and Girls' Sheep Clubs.

Added to all of these policies there is the fine piece of work along investigational lines conducted during the past four or five years by the National Research Council in relation to wool production on the range; also, the exhaustive and valuable "Economic Survey of Sheep Ranching in Western Canada," carried out under the auspices of the Economics Branch, Department of Agriculture, Ottawa.

In all of the above the different provinces have co-operated to the utmost with officers of the Dominion Department of Agriculture and much good work has been accomplished. My contention is, however, that the problem has yet to be tackled in a national way in order to determine the best line of procedure, as a general scheme designed for British Columbia conditions is undoubtedly very different from, and perhaps totally unsuited to, the Provinces of Ontario and Quebec. And by the same token, the scheme of things to be outlined for the foothills of the Rockies or for Southern Alberta is not by any means applicable to Prince Edward Island. I also feel, and this I cannot emphasize too strongly, that far too much attention has been directed to the smaller farm flock owner rather than to the problems of the small and large sheep rancher of Western Canada who, to my mind, constitutes the backbone of the industry or, as it were, the base of the triangle upon which the rest of the structure should be

built. Therefore, even though this paper is being presented to the Eastern Section of your Society, I would crave your indulgence if from now on I appear to be centering my remarks around the ranching interests, having in mind, of course, that there are two distinct phases to our Canadian sheep industry; namely, ranch and farm.

I recognize, of course, the value of the farm flock and the place which it holds everywhere throughout the Dominion, but I base my plea for more attention to the ranch interests upon the following facts:—

1. In recent years the Province of British Columbia has surpassed all other sections of Canada in the expansion of its sheep industry, and it is perhaps safe to say that the majority of the new flocks established in that province trace their origin to the large range flocks of Southern Alberta and Southern Saskatchewan. The most successful operators in British Columbia keep replenishing their breeding flocks every few years with these range ewes off the prairies, and by the consistent use of Down rams with recognized breeding they are able to dispose of their growthy and milk-finished lambs during late August and September direct from the higher and succulent grass areas of that province.

2. The rapid development and profitable returns during the past three years from the feeding of western range lambs, both on the irrigated farm areas of the West and this past season to the extent of some 10,000 head on Ontario farms, provides ample evidence of the place range sheep occupy in the production of these very hardy and satisfactory "feeders."

3. No section of Ontario has shown more interest in sheep, and no more remarkable development can be recorded than in the Rainy River District. The greater number of these Rainy River flocks have been started with the same range ewes from the prairies, and this incidentally prompts me to suggest that there are further possibilities in this connection throughout the older parts of Ontario and even down into Quebec and the Maritimes.

In short, when considering any National development, I believe that it should embody the ranching interest as the main source of supply for farm flocks and feeder lambs, and that towards this end every effort should be made to maintain and improve the inherent hardiness and grazing ability of the range ewe, coupled with her good quality wool production.

This, incidentally, brings me to the various constructive phases which I would like to place before you for discussion:—

1. BREEDING POLICY

In the preparation of this material I have endeavoured to secure a concensus of opinion from different authorities across Canada, and when it comes to the consideration of a satisfactory breeding policy I know of no more outstanding authority than Dean A. M. Shaw of Saskatoon, who states in a recent letter:—

"I still think that the fine-wool sheep (Rambouillet) is undoubtedly the foundation for the Great Plains area of Western Canada. There seems no reason to doubt but that this breed should be improved somewhat in one of three ways:—

"*First*, by straight selection.

"*Second*, by the introduction of a coarser and longer stapled type such as the Corriedale.

"*Third*, by the introduction of a mutton type possessing pure fleece such as the Ryeland.

"I do not know of course just what these combinations would eventually produce, but I am quite sure that they are worth while trying in an effort to establish a type that will be better adapted to the Great Plains area of Western Canada. It may also mean that a number of our so-called domestic breeds must be revised, as it were, and improved along more practical lines, while others of these domestic breeds should probably be eliminated entirely."

Then, again, Dean Shaw in presenting a paper along this same line last November, said:—

"The lack of any settled breeding policy among range sheepmen has made it evident that there is a great need for some research work with regard to breeds of sheep and breeding systems suitable for the range area in Southwestern Saskatchewan and Southern Alberta. Breeds in use or which have been used in this area either as ewes, rams or crossbreds include Rambouillet, Corriedale, Cheviot, Romney Marsh, Lincoln, Cotswold, Leicester and the Down breeds, no one of which has proved entirely suitable in itself.

"Many of the ranchers try to control the uniformity of their bands by 'hit-and-miss' methods, using fine-wool or longwool rams to raise or lower respectively the percentage of finewool blood in their bands; and, although each rancher may have some definite type in mind as an ideal towards which to strive, yet the methods he adopts are not such as may assure him of any permanent success in his operations. The use of crossbred rams by the sheep rancher in any other but an experimental way is a practice to be severely condemned if the uniformity of his band is to be maintained.

"It is conceded by most that the Rambouillet ewe is the best purebred for range purposes, so far as quality and quantity of wool, hardiness and grazing habits are concerned. On the other hand, she is not ideal when considered from the standpoint of commercial lamb production. Rambouillet or finewool feeder lambs are not of good mutton conformation and are apt to finish at weights too heavy for the market, although their daily gains may be good.

"There are two distinct methods whereby the present situation might be improved. Firstly, a breeding system might be adopted similar to that in general use in hill flocks in Great Britain. The problem of the hill flock master there is somewhat the same as that of the range sheepman. Sheep on the heather and grass hills must be hardy, active, well woolled, able to withstand severe weather and exist on scanty pasture and be active enough to travel the hill each day. The Blackface and Cheviot ewes are hardy and active, but are not ideal from the commercial market standpoint, the former especially being a slow-maturing and small animal. Most flock masters, therefore, use Border Leicester rams on the hill to produce grayface and half-breed lambs. Those lambs are excellent

examples of hybrid vigour and are very suitable for market purposes. Some of the ewe lambs are kept and bred to Down rams, the offspring being all sold as market lambs and no further crossing takes place. A similar system might be adopted here. The Rambouillet ewes might be bred to medium wool rams of mutton type to produce market lambs, all of the lamb crop being sold each fall and replacements for the ewe bands bought or raised separately.

"The second possibility is the evolution of a new breed combining the hardiness, fleece quality and grazing habits of the finewool with the superior mutton conformation and early maturity of one of the medium-wool or longwool breeds. There have been attempts in the past to evolve a breed in this way. Some of those attempts have been fairly successful, for example, the Corriedale in New Zealand produced by crossing Lincoln and Leicester rams on Merino ewes and selection amongst the progeny. The United States Department of Agriculture is experimenting with crosses of longwool and finewool breeds and has produced the Columbia by using a Lincoln ram on Rambouillet ewes. The Panama is the reciprocal cross to the above and the Romeldale has been produced by using Romney Marsh rams on Rambouillet ewes. Both of these have been developed by individual ranch owners in the United States. There has never been any controlled experimental work of this kind, using a finewool and a mediumwool breed; and it would seem that, for western Canadian conditions, this might be a better combination than the longwool and finewool owing to the large size and relatively coarse fleece of the latter cross (the Columbia is larger than the Corriedale and the fleece grades about $\frac{1}{4}$ Blood; the Romeldale is also larger than the Corriedale and the fleece grades about $\frac{3}{8}$ Blood).

"Although in any one individual, wool quality and mutton conformation seem to be incompatible or antagonistic to some extent, it should be possible to evolve a type which, although surpassed by the finewool parent in fleece quality and by the medium-wool parent in mutton type, is superior to either as a dual-purpose animal; that is, a hardy type which will yield a fleece of good weight, quality and staple length, graze well and which will produce market lambs of good type. If such an attempt is made, the Rambouillet seems to be the logical choice for the finewool parent. The selection of a medium-wool parent is not so simple, but it is evident that none of the Down breeds is suitable on account of black fibre in the fleece. Of the Whitefaced medium-wools, the Ryeland seems to offer the most hopeful possibilities. So far as the Corriedale is concerned, there are several objections to its use as mediumwool parent. It is a breed of recent origin and is, therefore, less homogeneous genetically speaking, than the older breeds. The extreme variation in Corriedale fleeces is due to the fact that this breed is not homogeneous for the factors controlling fleece quality. Further, it already contains a considerable proportion of Merino breeding, which fact would complicate selection for an intermediate type in the F_1 generation. It it is desired to combine the best possible mutton type with the valuable characteristics of the finewool, surely it is a logical assumption that the better the mutton type of the mediumwool parent, the greater chance there is of satisfactory mutton type in the offspring; and, as the Ryeland is clearly superior to the Corriedale in mutton type, the former seems the logical choice."

These remarks of Dean Shaw's are not necessarily conclusions, but I take it they are rather ideas from which conclusions may be deduced, and it is up to all of us to strive towards some scheme of experimenta ion that will assist the Western rancher in working out his problem. We have something really tangible to start with and from which it should be possible to evolve a breed or a type with all the necessary characteristics such as hardiness, grazing ability, suitable wool and better mutton. Undoubtedly more rigid selection should be practised on every ranch, not only as to the most suitable type of ram, but also correct mating, and if the right type of ram is not available or cannot be imported, then we must seriously consider the establishment of stud flocks possessing the desired type.

Then, we have the question of "Breeds," of which there would seem to be at least twice too many, and surely when considering this phase some attempt should be made to deal with it finally on the basis of the fewest possible breeds to suit the particular conditions under which the sheep are to be produced. This would naturally mean less attention to the breed for which each farmer or rancher has a liking, and with which he would like to work, regardless of how it fits into his climatic and feed conditions.

2. LAMB FEEDING AND MARKETING

Much fine progress can be recorded in the lamb feeding operations of the past three or four years, but I believe we still have a long way to go in perfecting a marketing policy which will be to the best interests of all concerned. Some method of standardization and more satisfactory grading must be evolved either on the hoof or on the rail so that settlement to the producer may be based more nearly upon the finished condition, weight and quality of the animal, thus carrying back to him full value for what he has produced and fed. A proposed grading system was drawn up three years ago and although I make no attempt to vouch for it as filling the necessary requirements, I am prompted to place it before this gathering mainly for the purposes of discussion.

Spring Lamb:—Young lamb from fall and winter lambs.

No. 1. Of choice quality—weight up to 40 pounds each.

No. 2. Of good quality—weight up to 40 pounds each.

No Grade. All lamb that does not come within the requirements of Grades 1 and 2.

Standard Lamb:—Lamb from spring lambs up to one year old.

No. 1. Of choice quality—weight up to 45 pounds each.

No. 2. Of good quality—weight up to 45 pounds each.

No. 3. Of good and choice quality—weight from 45 to 55 pounds each.

No. 4. Of medium quality—weight up to 55 pounds each.

No Grade. All other lamb.

Mutton Grades:—Ewes and Wethers over one year old.

No. 1. Of choice quality—weight up to 65 pounds each.

No. 2. Of good quality—weight up to 75 pounds each.

No Grade. All other mutton.

Rams and Stags.

No Grade.

There seems to be a great difference of opinion as to the proper market weights for finished lamb, and one may well contend that the type of breeding and the feed conditions should influence any decision. For instance, the weight of lamb produced on the range is a vital factor when it comes to feeding and finishing to the consumer's taste. This has a direct bearing on the success or failure of the rancher, and I am not too sure that the finished western lamb when it leaves the feed lot, either here or in Western Canada, should be penalized for being too heavy at 100 pounds. This means, on the average, a 48- to 50-pound carcass, and many retailers maintain that the 50-pound carcass, particularly in the fore-quarters, cuts out to better advantage than the 40-pound carcass. Careful investigation should be made of public demand and economic retailing before the definite standardization of weights. So far as the producer is concerned, it is unprofitable to raise feeder lambs under range conditions weighing less than 70 pounds off the ranch. In fact, the Economic Survey of Sheep Ranching Conditions in the West, conducted by the Dominion Department of Agriculture, Ottawa, showed very clearly that the ranchers who are least successful are those turning off lighter weight lambs. Then, too, the feeder cannot operate successfully with less than a 30-pound gain —both operators need the breaks—and if the consumer is being satisfied with the right kind of meat, as I believe he is, this is the phase which we should study more closely.

3. WOOL MARKETING

This side of the industry has perhaps received a good deal of attention, but it is rather startling to consider the quantity of wool, more particularly in the Eastern Provinces, still being marketed as "junk" through the itinerant pedlar and dealer. The farmer who follows this practice knows little or nothing about the value of his product or whether the market is up or down, and, of course, when one figures that the average Eastern farm clip is at best not larger than 150 pounds, there is not a great deal of incentive for the producer to give it the care and attention that is required. However, something might be incorporated into a National Policy that would eventually make more and more of our sheep raisers, both East and West, realize that they have a moral obligation or interest in the industry by doing their bit to remove Canadian wool from the junk pile.

4. PURE-BRED FLOCKS

As intimated before in this paper, there are too many breeds of sheep, and if certain definite types can be established with one or two breeds of swine, the question immediately comes up, why not with sheep? Those breeds best suited to the production of market lamb should quite naturally be in favour, and some other breeds suitable for crossing with the Merino ewe of the range, having wool improvement and better body conformation in mind would, of course, serve their useful purpose. All owners of pure-bred flocks should be educated more and more in the matter of rigid selection and culling—there is no place for the nondescript even for commercial purposes—and no effort should be spared to eliminate it.

5. EDUCATION AND PUBLICITY

If any properly organized and directed National Policy leads to increased production, there must be a corresponding increase in consumption and only a well-directed publicity effort will keep the two running hand in hand. We still have with us, because of our varied conditions previously referred to, the early spring lamb, the fall lamb and the winter-fed lamb. Lambs are usually looked upon as "lamb" right up to the end of the feeder season, which sometimes extends into April. In the Eastern Provinces, feed, climate and other conditions are such that there is a good deal of room for expansion in the production of early lamb. The larger urban centres are fond of delicacies at certain seasons, and the hot-house or milk-fed or Easter lamb presents some wonderful possibilities. If the great bulk of our Eastern lambs could be passed into consumption by September, the way would then be reasonably clear for the fall lamb and the winter-fed lamb of Western Canada.

In the main, we must grow lambs of the right quality that will permit of the meat being retailed everywhere in the domestic market in direct competition with other meats.

The producer is entitled to expect that through some nationally devised program he can convince his consumer market that there is something more to a lamb than just leg of lamb and lamb chops. Butchers and purveyors generally still have to be taught how to merchandise a lamb carcass. Up to the present, in many shops, it would appear that hind quarters have been sold for enough so that the front quarters might be lost or given away and still leave a profit. Moreover, a consumer needs to be assured of getting lamb meat when it is ordered and not a chop or roast from some old lunger ewe. We need some instruction as to how these cheaper cuts may be best utilized. Our meatmen, as well as consumers, need to know how to make such things as Saratoga chops, mock duck, rolled shoulder, crown roast and many other fancy ways of serving lamb from the forepart of the carcass. In other words, an active and widespread publicity and educational campaign must needs be a part of any national movement.

6. NATIONAL SHEEP COMMITTEE

As intimated, the appointment of a permanent National Sheep Committee representing all interests was urged four years ago but no action has yet been taken. Such a committee is just as timely today, in fact more so, and although I do not wish to suggest how large such a committee should be, it seems to me that it should carry representation from at least every distinct phase and interest of the industry. This would embody the range and farm flock interests of British Columbia, the same interests on the prairies, a representative conversant with farm flock conditions in Ontario, likewise in Quebec and again in the Maritime Provinces. Wool should be represented and, naturally, those government interests, both Dominion and Provincial, that would have something to do with the promotion of any carefully thought-out National Policy.

Concluding, may I apologize for the length of this paper and, at the same time, acknowledge with thanks the interest displayed in the subject by all parties with whom I have been in touch. I only hope it may all be productive of full discussion in the best interests of the industry.

Résumé

Un système national d'élevage de moutons. W. H. J. Tisdale, Coopérative canadienne des producteurs de laine Limitée, Toronto, Canada.

L'auteur insiste sur l'occasion qui se présente d'augmenter la population ovine au Canada. Il fait remarquer qu'en des années récentes, la Colombie-Britannique a dépassé toutes les autres provinces par l'expansion de son industrie ovine. Comme cette expansion était due principalement à l'introduction des moutons venant des grands herbages de l'Alberta et de la Saskatchewan, il discute l'importance qu'il y aurait à élever des types nouveaux et plus convenables de moutons sur ces herbages. Il recommande d'étudier les méthodes d'alimentation et de vente des agneaux et propose des catégories de marché. Il met en lumière la valeur de la vente coopérative de la laine. Il est également d'avis qu'un comité national d'industrie ovine devrait être établi, et une propagande instructive conduite pour encourager l'emploi de la laine canadienne et de la viande d'agneau et de mouton.

ANNUAL MEETING OF THE CANADIAN SOCIETY OF ANIMAL PRODUCTION

(Eastern Section)

The sixth Annual General Meeting of the Canadian Society of Animal Production (Eastern Section), was held at the Ontario Agricultural College, Guelph, Ontario, on June 12, 1935, under the Chairmanship of the President, Mr. C. F. Bailey, Superintendent of the Dominion Experimental Station, Fredericton, N.B.

The papers and committee reports presented at this session, and included in this number of *Scientific Agriculture* were assembled by the Secretary of the Society, Mr. E. B. Fraser, Animal Husbandry Division, Central Experimental Farm, Ottawa, Ontario.

The following officers were elected for the year 1935-36:—

President—Mr. C. F. Bailey, Dominion Experimental Station, Fredericton, N.B.

Vice-President—Professor A. R. Ness, Macdonald College, Que.

Secretary-Treasurer—Mr. E. B. Fraser, Central Experimental Farm, Ottawa, Ont.

Maritime Director—Mr. W. W. Baird, Dominion Experimental Farm, Nappan, N.S.

Quebec Director—Mr. S. J. Chagnon, Deschambault Farm, Deschambault, Que.

Ontario Director—Professor R. G. Knox, Ontario Agricultural College, Guelph, Ont.

THE DEVELOPMENT OF THE WAX-PLUCKING METHOD FOR POULTRY[1]

N. H. GRACE[2]

National Research Laboratories, Ottawa, Canada

INTRODUCTION

With the increased tendency on the part of farmers to finish, kill and dress their poultry properly at home, a constant search has been maintained by officials of the Dominion Department of Agriculture in charge of market poultry improvement to find ways and means which will improve and make less onerous the most difficult parts of the operation and which will facilitate the finishing and sale of the poultry over a wider period of the year.

A great many people who have mastered the art of a successful stick in killing, approach the time of dressing poultry with hesitancy on account of the possibility of tearing and disfiguring the carcass, more particularly those of crate-fed well finished poultry and also on account of the arduous task of removing the pin feathers.

For a year or more it has been known that several large plants in the United States have been using a preparation of wax to facilitate plucking and also that it was maintained that this could only be used in conjunction with the semi-scald or wet pluck, a method of plucking not endorsed for use in farm practice in Canada. In most cases rather elaborate and expensive equipment has been used for wax-plucking.

It was felt that the possibilities for wax-plucking dry-roughed birds were worthy of further investigation and under direction of the Director of Research of the Department of Agriculture, officers of the Poultry Services of the Livestock Branch conferred with officers of the Chemistry Division of the National Research Council and a co-operative project was undertaken.

The National Research Council provided research facilities, the Livestock Branch the trade knowledge and laboratory assistants, and the Experimental Farms Branch the necessary live birds with which to work. The object was to find a formula for and method of wax-plucking that would supplement the dry rough plucking in use on Canadian farms and one for which the necessary equipment would be both simple and inexpensive. During the investigation, some 150 wax mixtures were prepared and tested.

Comparatively little definite information was available regarding the use of wax-plucking in the United States. Literature on the subject was non-existent with the exception of one U.S. patent. Apparently the method involves killing the bird, semi-scalding or cold-scalding in water at a temperature of 128° F. for broilers, 129° F. for chickens and 130° F. for fowl. The duration of immersion is about one minute. The rough feathers are then removed, and the bird dried and coated with a molten wax

[1] Paper prepared June 12, 1935, for the annual meeting of the Canadian Society of Animal Production (Eastern Section).

[2] Assistant Research Chemist.

preparation. The wax coating hardens and comes away readily, taking with it the remaining feathers, pin feathers, hair and scurf, leaving a carcass with a most attractive finish and an excellent sales appeal.

EXPERIMENTAL STUDY

The object of the work was the development of a suitable wax mixture which could be used with inexpensive equipment and little exact control. The experimental features of the problem may be discussed from the point of view of wax mixtures and methods of using the wax. Available information indicated that the following substances were being used in the wax mixtures for plucking—paraffin, suet, rosin, beeswax, etc. The method of use has been mentioned in the introduction.

Considerable difficulty was encountered in preparing a suitable wax mixture. Several important considerations had to be met. The wax required suitable fluidity and spreading power in order to penetrate around the roots of the pins, and it had to harden with the formation of a coherent elastic coat which would come away readily in large flakes. A further consideration was suitable fluidity over a moderate temperature range. Several mixtures with good pulling properties were prepared, but their suitability was confined to use over a narrow temperature range which would have been impractical with comparatively inexact methods of use. Great difficulty was encountered in developing a suitable basis of comparison. Different waxes were compared in terms of tensile strength, hardness, viscosity and surface tension. However, these results could not be directly translated into terms of pulling power. One of the most effective methods of comparison was to allow wax to harden on a given area of quill surface and then to measure the pulling force required to remove it.

The methods of applying the wax to the bird gave some difficulty, since the value of a given wax has been found to depend very considerably on the method of use. Some of the earlier mixtures prepared and originally found quite unsuitable would have given much better results in terms of the technique which was finally developed. Certain mixtures gave excellent results with semi-scalded birds whereas the results were quite out of the question when dry-plucked birds were considered. The reason for this fact will be discussed under semi-scalding. Development of a suitable wax mixture was greatly aided when the method of semi-scalding was clearly understood and the importance of partial cooling of the dry-plucked bird prior to waxing was recognized. Co-ordination of these various points resulted in the preparation of a very suitable and inexpensive wax mixture.

ROUGHING THE BIRD FOR WAXING

It has been pointed out that the waxing of dry-plucked birds has been one of the main objectives in this work. Most classes of dry-roughed birds can be successfully wax-plucked by following the technique which is about to be described. However, there are two sub-classes of birds which must be excepted: very pinny young birds of the broiler type, and moulting birds. These require semi-scalding if satisfactory results are to be obtained. The technique for dry-roughing and semi-scalding follows.

(a) Dry-roughing

In dry-plucking, the bird is stuck in the usual manner and the bulk of the larger feathers are quickly removed, leaving many residual feathers, pin feathers, hairs, etc. Following roughing the bird must be allowed to lose a part of the body heat. If the warm carcass is wax coated immediately there is a serious tendency for smears of wax to be left on the body. The efficiency of the pulling job is quite satisfactory, but smearing of wax must be avoided and can be prevented by partial cooling prior to wax coating. In our experience this cooling has been attained by simply hanging the bird for from 1 to 2 hours. Good results follow when the skin temperature is reduced to around 80° F. though a temperature in the neighbourhood of 75° F. is to be preferred if it can be attained without too much difficulty. The importance of this partial cooling should be stressed as good results are very largely dependent on this one step in the procedure, and the recognition of its importance was of great assistance in the development of a satisfactory wax mixture.

(b) Semi-scalding

There is every indication that semi-scalding is not desirable from the point of view of the quality of the dressed bird. A number of comparisons have been made on this point and the evidence in favour of the superior appearance of the dry-roughed bird is definite. Semi-scalding is, however, absolutely necessary in the case of the very pinny bird with short poorly developed pin feathers. The broiler and moulting bird require semi-scalding if an efficient wax-plucking job is to be done.

Semi-scalding consists in immersion and agitation of the bird in warm water for a period of about one minute. The water temperature should be 128° F. for broilers and 130° F. for fowl. These temperatures must be maintained with considerable care, as the water temperature in semi-scalding is the most exact operation involved in wax-plucking. The semi-scalded carcass is roughed and then hung until completely dry. Simply hanging for 1 hour results in satisfactory drying in most cases though, if desired, some sort of air current can be used to speed it up.

There are several factors involved in the effect of semi-scalding. Examination of pin feathers under magnification of about 15 diameters shows a scaly layer at the upper end of the pin just below the feather tuft. If this short scaly coated pin is covered with wax, the scale lifts off on removing the wax coat. The feather tuft tends to come away, leaving an empty hollow quill in the bird. Semi-scalding removes this scaly surface in large measure and allows direct contact of wax to quill. Further, the feather tuft is somewhat constricted in size following the water treatment and a larger amount of the pull comes on the quill. In consequence, excellent pulling results. In addition to the surface effect, semi-scalding probably partially coagulates proteins and renders the actual removal of the pin feather from the skin a little easier. This is readily observed if one compares the roots of the pin feathers of dry-plucked and semi-scalded birds. The semi-scalded pin slips out much more readily and does not leave the jagged root found in the dry plucked pin. The practical consequence of this is the much greater ease with which the wax coat can be removed from the semi-scalded bird. This feature will be particularly important from the point of view of commercial practice as it cuts down the unit time for removing the wax coat to about one-half.

In discussing semi-scalding, it may be of interest to mention recent work on the wax-plucking of forced-fed, 11-week-old, young ducks. These ducks are simply full of short quills. Ordinary semi-scalding has been found to have no effect when compared with dry-plucking. However, the addition of a small amount of soda ash to the water used in semi-scalding (temperature at 128° F.) resulted in great improvement. These results have not been followed very far and the conclusions cannot be taken as final, but it is felt that some further light may be thrown on the whole question of semi-scalding.

WAX COATING

The wax coating of roughed birds—both dry-roughed and semi-scalded—will be discussed under the following headings: *(a)* equipment; *(b)* the wax and the temperature of use; *(c)* dipping the bird in wax; *(d)* hardening the wax coat; *(e)* removing the wax coat, and *(f)* reclaiming the wax.

(a) Equipment

For small-scale farmers and dressers of poultry, very simple equipment can be used with excellent results. Naturally, plant operators and large dressers of poultry would be well advised to use somewhat larger and more elaborate equipment in order to speed up the operation. However, any individual intending to pluck say 50 birds at a given time can use a kettle or other suitably shaped container which holds around 30 lb. of wax. This may be placed in a tub and surrounded with warm water to maintain the temperature. A small vessel holding hot wax, which will be added from time to time to keep up both the volume and the temperature, is required. A dairy thermometer and strainer complete the equipment.

(b) The Wax and the Temperature of Use

The wax is melted down over any convenient source of heat and it should be put on to warm an hour or two before it is required for use. The only precaution to be pointed out is that this wax will burn although it is not, by any means, highly inflammable. Ordinary care to avoid spilling large quantities on a hot stove or heater is advisable. The wax can be used over a temperature range of 125° F. to 136° F. For dry-roughed birds, temperatures around 130° F. are quite satisfactory; for semi-scalded birds, temperatures around 125° F. are to be preferred as it is a little more simple to build up a coat of suitable thickness. In the course of ordinary operation comparatively little attention is required to maintain the temperature. Possibly 3 adjustments in an hour will be necessary with the small 30-lb. wax vessel. The wide range of temperatures which can be used is an imporant feature.

(c) Dipping the Bird in Wax

The cool dry-roughed bird or the dry semi-scalded bird is dipped into the wax. The first dip should be of a duration of from 3 to 5 seconds and the bird should be agitated during this time to ensure penetration of the wax to feathers and pin feathers. The carcass is then removed to drip for a few seconds. This is followed by a quick dip. With wax temperatures around 125° F. two dips will probably be adequate; with temperatures around 130° F. three dips will likely be required to give the coat the desired strength. An extra dip or two may be required for still

higher temperatures. With a little practice the operator can adjust the number of dips for variations in wax temperature.

(d) Hardening the Wax Coat

The wax coated bird may be hung up and the coat allowed to harden by cooling in the air. This will take from 15 to 30 minutes. It is usually desirable to dip the coated carcass into cold water for a few seconds prior to removing the coat. If speed is required, the coated bird may be plunged immediately into cold water and left there from 2 to 5 minutes. In this way the wax coat may be taken off within 5 minutes of wax dipping. The liberal use of cold water is to be recommended in warm weather. The hardening of the wax coat is not an exact operation and does not require great attention. The wax is hardened to the point where it is just hard enough to crack and tear away in large pliable flakes and there is quite a range over which this can be attained. If there is a tendency for the wax to come off in thin brittle pieces it will be necessary to increase the thickness of the coat by another dip, and possibly to decrease the cooling. On the other hand, if the wax is very sticky and soft on removal, the coat is either too thick or insufficiently cooled.

(e) Removing the Wax Coat

The hardened wax layer can be removed readily and quickly. The first operation is to pull down the wings and crack the wax. This is followed by holding both legs and forcing up the body in such a way as to crack the wax along the sides. Large pieces should come away if the coat has been properly cooled and hardened. In our experience, the wax coat should come off semi-scalded birds in about 45 seconds, and a minute and one-half will be an average time for removing the wax from dry plucked birds.

(f) Reclaiming the Wax

The flakes of wax containing embedded feathers, pin feathers, hairs, etc., may be readily melted down and the refuse removed by straining. In this way the wax can be used over and over again. With moderate care to avoid loss of wax in removing the coat, not more than 1 lb. of wax should be lost in the wax-plucking of 40 birds. In the case of plant opertions where a small press will likely be used to remove wax from feathers, etc., the loss should be even less. Considering the wax costing about 10 cents a pound, it is seen that the cost per bird will not exceed $\frac{1}{4}$ of a cent.

THE BLOOM OF DRESSED POULTRY

Some attention has been given to the study of possible treatments to preserve the bloom in storage poultry. It was suggested that certain ingredients could be incorporated in the wax mixtures used for plucking with the result of still further improving both the appearance and keeping qualities of the bird. While this was found impossible, a study has been made of some simple treatments which appear to be effective in maintaining the bloom of the birds in storage. There is some indication that these surface treatments may retard the growth of microorganisms. This project is under way but it is unwise to go further than merely to point out the interesting possibilities.

CONCLUSION

A satisfactory wax has been developed which may be used with very simple equipment over a comparatively wide range of temperatures. It hardens readily but gives a good coat over a fair range. The waxing of dry-plucked birds gives excellent results for nearly all types of birds. Semi-scalding is necessary in some cases and fairly definite information regarding the nature of semi-scalding in relation to pin feathers has been determined. This method is sufficiently simple to permit of use on the average farm and the cost is slight. The excellent appearance of wax-plucked poultry is such as to warrant considerable use of this modern method of poultry dressing. While there is undoubtedly a saving of time in the case of many birds and particularly in the case of large scale operations, the most important factor is the fine appearance which is obtained.

Résumé

L'emploi de cire pour plumer les volailles. N. H. Grace, Laboratoire national des recherches, Ottawa, Canada.

Une cire satisfaisante a été développée; elle peut être employée par une échelle de température assez variée et n'exige qu'un outillage très simple; elle se durcit rapidement et forme une bonne couche d'épluchage. Le cirage des oiseaux dégrossis à sec donne d'excellents résultats pour presque tous les types de volailles. Un échaudage est nécessaire dans certains cas et certains renseignements précis sont donnés au sujet de la nature de l'échaudage pour l'enlèvement des plumes naissantes. Le procédé est simple et économique; il peut fort bien être employé sur la ferme. L'excellente apparence que présentent les volailles plumées justifie l'adoption générale de ce moyen moderne d'habillage. Le cirage permet de réaliser une économie de temps pour bien des oiseaux, surtout lorsque le nombre à plumer est considérable, mais l'avantage le plus important est que les oiseaux plumés par ce moyen présentent une belle apparence.

THE CEREAL GRAINS AND THEIR USE IN POULTRY NUTRITION[1]

I. Hatchability Studies

J. B. Smith[2]
Ontario Agricultural College, Guelph, Ont.

HATCHABILITY STUDIES

The use by the farmer of home grown feeds for egg production and hatchability is of some importance. With this thought in mind, experimental feeding trials have been conducted under carefully controlled conditions at this Department over a number of years. These studies are continuous and this paper deals only with some of the results in egg production and in hatchability secured over the past four years.

Our earlier investigations on the role of cereal grains in poultry nutrition were planned so that the birds were raised on diets, differing in the kind of cereal, from the time of hatching until well on in their pullet year. At maturity the only change made in the diet was to increase the amount of alfalfa. The control pen was fed a mixture of the four cereals with a mixed animal protein supplement of milk (powdered) and fish meal, alfalfa and cod liver oil, as well as oyster shell, bone meal and grit (in separate hoppers).

The influence of the four cereal grains studied on egg production and hatchability is shown in Table 1.

Table 1.—The influence of cereals on egg production and hatchability

Cereal	Average egg production per hen per month	Percent of hatch	Lbs. of feed consumed per hen per month
Mixture	14.6	80.0∓0.82	6.7 lbs.
Corn	9.8	63.9∓1.77	7.0 lbs.
Wheat	10.2	73.7∓1.27	7.8 lbs.
Oat groats	6.6	64.7∓1.77	6.0 lbs.
Barley	8.6	75.9∓1.25	6.0 lbs.

Table 2.—The influence of cereal grains on hatchability*

Cereal	Hatchability
Mixed	61.3 ∓ 1.07
Corn	62.1 ∓ 1.07
Oats	60.2 ∓ 1.21
Barley	43.5 ∓ 1.16
Wheat	20.6 ∓ 1.15

*The birds were reared under range conditions and placed on the various cereal grains at maturity.

The egg production varied widely with the kind of cereal grain fed, while the hatchability was surprisingly high for both the wheat and the barley pens. There is also a variation in the consumption of feed per month (as shown in Table 1). The birds on wheat consumed 1.8 lbs. more per month than did either the barley or oat groat pens.

When birds were raised under the usual range conditions and placed on the various cereal grains at maturity, the results in hatchability were in some cases seriously lowered as shown in Table 2.

[1] Paper read before the annual meeting of the Canadian Society of Animal Production (Eastern Section), at the Ontario Agricultural College, June 12, 1935.

[2] Poultry Department.

TABLE 3.—GRAIN AND PROTEIN COMBINATIONS AND THEIR EFFECT ON PRODUCTION AND HATCHABILITY*

en No.	No. of birds		Ration	Average egg production per month	Per cent of Hatchability	Mash consumption	†Protein consumption	Shell (5 mos.)	Bone Meal (6 mos.)
1	25	1	Crushed grain mixture plus ribbon milk (separate container)	17.3	74.0	53.5	4.69	.957	.447
2	25	1	Crushed grain mixture plus powdered milk (separate container)	16.3	70.0	53.5	4.01	.76	.306
3	25	1	Crushed grain mixture plus semi-solid milk (separate container)	17.3	75.0	54.2	12.5 (3.84lbs.day)	.85	.76
4	30	2	Crushed grain mixture plus 1 gal. skimmilk daily (separate container)	16.0	72.0	44.6	6.56 gal.	.767	.35
5	35	3	Separate hoppers of crushed wheat, crushed oats, crushed barley, semi-solid buttermilk, ribbon buttermilk, powdered buttermilk, fish meal and beef scrap.	17.1	66.0				
6	25	1	Crushed grain mixture plus hopper of mixture of equal parts milk, powder, meat meal, fish meal.	16.5	50.0	51.3	4.44	.74	.15
7	25	1	Crushed garin mixture plus concentrate of fine material from cafeteria mixture less soya beans and peas.	16.0	20.0	50.6	6.06	.91	.11
8	25	1	Crushed grain mixture plus concentrate of meat, fish, milk wheat germ, soya beans, peas, cod liver meal, salt.	16.7	25.0	49.8	6.11	.766	.126

*Crushed Grain Mixture for all pens, with the exception of No. 5.

Equal parts by weight { Crushed oats, Crushed wheat, Crushed barley }

All pens: hard grit, oyster shell and bone meal in hoppers; alfalfa hay fed daily and cod liver oil, one pint per 100 lbs. of feed.

†No grain was fed with the crushed grain mixture.

The animal protein supplements used in these trials were changed from [10]milk and [7]fish meal to a mixture of milk, meat meal and fish meal (5% of each). It may be seen from a comparison of Table 1 with Table 2 that the mixed cereal ration declined in hatchability from 80 ∓ 0.82 to 61.3 + 1.07 when a change was made in the mixture of animal protein supplement. From numerous other trials in our studies in hatchability a mixed animal protein supplement of milk and fish meal gave much higher hatchability than did one of milk, fish meal and meat meal. The greater differences however, with the wheat and the barley pens show them to be deficient in hatchability. With wheat and barley there was a high first week death rate which cause a severe peak in the curve constructed for embryonic mortality occurring in each case on the third day of incubation.

For the two years work, it would seem highly probable that the adaptability of the ration and the "survival of the fit" are factors worthy of some consideration in view of the fact that with the wheat pen in particular the mortality during the growing period was excessive.

A crushed grain mixture of equal parts by weight of wheat, oats and barley was used with various animal protein supplements. In some cases the supplements were used with the crushed grain mixture alone, while in others they were fed in combination. For the sake of comparing the efficiency of milk, in its various forms, it was fed with this grain mixture as four different products: liquid skimmilk, ribbon powdered buttermilk, powdered buttermilk and semi-solid buttermilk.

The crushed grain mixture with the supplements fed in separate hoppers gave excellent egg production in all trials (Table 3). In hatchability however, the pens on milk in its various forms gave satisfactory hatches while the others were only fair with the pens on a concentrate especially low. It has been observed in our other studies that milk contains the factor or factors required for hatchability, while meat meal and fish meal may be deficient in this respect.

Buckwheat is grown in many sections of the province of Ontario and is used to a considerable extent in live stock feeding. To place some value on this particular cereal from the standpoint of egg production and hatchability an experiment was planned to use it in various cereal and animal protein combinations. The use and abuse of buckwheat in the ration fed for laying is shown in the following table.

TABLE 4.—THE USE AND ABUSE OF HOME GROWN FEEDS*

Mash	—	Grain mixture	Egg production	Animal protein	% hatch
Oats and barley (crushed)	Milk	Wheat and buckwheat	16.5	9.6	65.7
Oats and barley (crushed)	Milk	Wheat and buckwheat	12.1	7.0	68.8
Oats and barley (crushed)	Milk	Wheat	14.1	10.0	72.3
Oats and barley (crushed)	Liver meal	Wheat and buckwheat	14.8	12.1	75.0
Oats and barley (crushed)	Meat meal	Wheat and buckwheat	14.7	9.7	12.6
Oats and barley (crushed)	Fish meal	Wheat and buckwheat	15.2	11.0	24.3
Crushed oats, wheat and barley, milk			16.0	†13.2	75.0

*Alfalfa fed daily; 1 qt. cod liver oil; bone meal; grit, oyster shell, in separate hoppers.
†This value was multiplied by 2 since no grain was fed with the crushed grain mixture.

SUMMARY

1. When birds have been raised from the time of hatching on a single cereal grain, with a mixed animal protein supplement, the egg production varies widely depending on the cereal grain fed. In hatchability the wheat and barley pens gave surprisingly good hatches due perhaps to the fact that the birds became adapted to the diet. There was a fairly heavy mortality during the growing period and the unadaptable may have died. In comparison with mixed cereals, the egg production and the hatchability were both decidedly in favour of the combination of cereals rather than the feeding of one alone in the diet.

2. Birds reared under range conditions and placed on single cereals gave quite different results in hatchability where either wheat or barley was fed. Both of the latter failed to promote good hatchability with a heavy death rate occurring in both instances during the first week of incubation.

3. A crushed grain mixture of wheat, oats and barley with milk gave excellent results in both egg production and hatchability over a two year period. This mixture with milk fed in four different forms gave only a small degree of variability in egg production and hatchability.

4. Buckwheat was used satisfactorily in combination with wheat with a mash of rolled oats and barley, when milk was used as the animal protein supplement.

5. If a farmer produces at least three cereal grains, milk and alfalfa, he need only buy cod liver oil, oyster shell, bone meal and possibly grit to have reasonable egg production and hatchability.

Résumé

Les grains de céréales et leur emploi dans la nutrition des volailles. Etudes de l'aptitude à l'éclosion. J. B. Smith, Service de l'Aviculture, Collège d'agriculture de l'Ontario, Guelph, Canada.

Lorsque les oiseaux sont nourris, à partir du moment de l'éclosion, d'une seule espèce de grain à laquelle on ajoute un supplément animal protéique, la ponte dépend dans une large mesure de l'espèce de grain employée. Au point de vue de l'aptitude à l'éclosion, les parquets nourris au blé et à l'orge ont donné des résultats surprenants, peut être parce que les volailles se sont adaptées au régime. La mortalité a été assez forte pendant la période de croissance; il est possible que celles qui n'ont pu s'adapter sont mortes. Cependant au point de vue de la production des œufs et de l'aptitude à l'éclosion, l'emploi d'une combinaison de céréales s'est révélé bien supérieure à l'emploi exclusif d'une céréale dans le régime. Les oiseaux élevés sur parcours et nourris d'une seule céréale ont donné des résultats très différents au point de vue de l'aptitude à l'éclosion quand ils recevaient du blé ou de l'orge. Tous deux ont produit des œufs qui couvaient mal et il y a eu une forte mortalité dans les deux cas pendant la première semaine d'incubation. Un mélange concassé de grain de blé, d'avoine et d'orge avec du lait a donné d'excellents résultats au point de vue de la ponte et de l'aptitude à l'éclosion pendant une période de deux ans. Ce mélange avec du lait, donné sous quatre formes différentes, n'a provoqué qu'un faible degré de variation dans la ponte et l'éclosion. Le sarrasin employé en combinaison avec du blé et avec une pâtée d'avoine roulée et d'orge, a donné des résultats satisfaisants lorsque le lait était employé en guise du supplément animal protéique. Si un cultivateur produit au moins trois espèces de céréales, du lait et de la luzerne, il ne doit acheter que de l'huile de foie de morue, des coquilles d'huîtres, de la poudre d'os et peut-être du gravier pour avoir une ponte et une éclosion raisonnables.

THE CEREAL GRAINS AND THEIR USE IN POULTRY NUTRITION [1]

II. Influence on Live Weight Gains and Distribution of Fat in Fattening Stock

W. A. Maw [2]
Macdonald College, Que.

The aim in feeding for finish or fattening is to add weight to the edible flesh, and mainly to add fat, both internally and externally, to the carcass. The degree of external fatness designates finish, but the degree of internal fat laid down in the muscle tissue determines quality of flesh; hence external fatness alone, if the main criterion of quality used in grading the product, may be misleading. A proper deposition of fat distributed in all parts of the body is essential to optimum quality in the carcass.

The character and amount of feed fed will largely influence the gains in live weight. The amount of protein in the ration does not necessarily indicate the value in possible live weight gains to be made. Neither does the amount of fat in the average fattening ration supply all the fat produced on the bird fed. It is common knowledge that the large deposits of fat which occur in the animal body must owe their formation, in a large part, to other constituents of the feed than the fat content. In many finishing rations the low fat content cannot account for the high percentage of fat in the finished carcass. Recent biochemical work has shown that certain of the decomposition products of carbohydrates may be utilized in this synthesis of fat. The carbohydrate of the ration, in excess of that used for immediate heat and energy, is converted to fat and stored in deposits for later utilization.

The individual cereals used are yellow corn, wheat, oats, and barley.

Feeding trials with large sized Rhode Island Red cockerels, group-fed for a period of twenty-one days, were carried out. Nine groups of three birds each, with individual body weights recorded, were run for each of the four cereals. The rations were made up with the individual cereal, in the whole form ground, and supplemented by six per cent animal protein containing three parts by weight of beef meal to two parts powdered milk. The ration was full-fed three times daily in a wet state.

There were distinct differences in the nature of the ration when prepared for feeding by mixing with water. The corn and barley rations took only slightly more than equal weight of water to dry feed, whereas the wheat and oats took approximately double the weight of feed in water for the mixture. The corn and barley rations soured quickly in comparison to the wheat and oat rations. The feed consumption per bird, however, with all four rations was quite uniform.

The gain-feed ratios, or grams gain per one hundred grams feed consumed, for the individual cereals are as follows:—

Cereal	Corn	Wheat	Oats	Barley
Gain/feed	12.91	11.26	9.74	10.69

These gain-feed ratios show the relative position of the four cereals on the basis of feed cost in relation to gain in live weight, the corn giving the highest gains, wheat, barley, and oats following in order.

[1] Paper read before the annual meeting of the Canadian Society of Animal Production (Eastern Section), Guelph, Ont., June 12, 1935.
[2] Assistant Professor of Poultry Husbandry.

The gain-feed ratio, however, does not give the whole story regarding relative value in producing quality of carcass. The distribution of fat in the carcass, irrespective as to whether it may give a slight difference in apparent finish to the carcass, does actually influence the quality of the edible parts.

Representative groups of three individuals from each ration were boned to determine the per cent of abdominal fat, external fat and skin, and flesh, as well as for chemical analysis of those parts.

Tables 1 and 2 illustrate the findings relative to the distribution of fat and composition of the tissues in the body of the chicken where fed the different individual cereals.

TABLE 1.—DISTRIBUTION OF FAT IN THE BODY

Cereal	% total fat	Flesh	Skin	Abdominal fat
Corn	13.4	30	55	15
Barley	12.1	26	59	15
Oats	12.1	22	57	21
Wheat	12.9	20	60	20

TABLE 2.—COMPOSITION OF TISSUES

Cereal	% fat in flesh	% fat in skin	% fat in abdominal fat
Corn	5.8	29	69
Barley	4.2	33	77
Oats	3.6	33	80
Wheat	3.4	34	77

These results definitely show that the different cereals cause the deposition of fats in the fattening cockerel in entirely different manners, i.e., cornmeal causes a high per cent of the total body fat to be deposited in the flesh and much less fat in the abdominal cavity and in the skin of the bird; whereas the cereals, barley, oats, and wheat, show the reverse in varying degrees.

These results were also borne out in the eating test when twenty persons tasted the cooked flesh, dark and white neat, and judged them for flavour, moisture, and texture independently without knowledge of the placing of the meats. The corn flesh was placed as having the highest flavour and as being moist, whereas the wheat flesh decidedly lacked flavour and was dry. The barley and oat flesh were intermediate to the corn and wheat flesh.

Résumé

Les grains de céréales et leur emploi dans la nutrition des volailles. Effet sur l'augmentation du poids vif et la répartition de la graisse dans les sujets d'engrais. W. A. Maw, Collège Macdonald, Québec.

L'auteur a constaté que la répartition des dépôts de graisse dans les cochets varie beaucoup suivant les céréales dont ils sont nourris. Par exemple, lorsque l'engraissement se fait à la farine de blé d'Inde, un gros pourcentage de la graisse totale du corps est déposé dans la chair et beaucoup moins dans la cavité abdominale et dans la peau de l'oiseau. C'est le contraire à différents degrés qui a lieu pour l'avoine, l'orge et le blé. Ces résultats ont été confirmés également par un essai de consommation où vingt personnes ont goûté la chair cuite, la viande foncée et blanche, et en ont fait l'appréciation pour le goût, l'humidité et la texture indépendamment, sans savoir comment ces viandes avaient été classées. Elles ont déclaré que les volailles nourries au maïs avaient le meilleur goût et que la chair était humide, tandis que celles qui étaient nourries au blé manquaient de goût et étaient sèches. La chair des volailles engraissées à l'orge et à l'avoine était intermédiaire entre le maïs et le blé.

THE NORTHERN FOWL MITE AND ITS CONTROL[1]

W. A. Maw,[2] W. E. Whitehead[3] and L. H. Bemont[4]

Macdonald College, Que.

INTRODUCTION

Under Canadian conditions, during the fall and winter months, the northern fowl mite, *Liponyssus sylvarium* C. and F., causes serious economic losses in mature fowl, and also great inconvenience to the operator in handling the stock. The life habits of the mite are obscure, especially with regard to its mode of aestivation during the summer months. At this season it leaves the body of the fowl and is of no further economic importance to the poultryman until late in the fall.

METHODS OF DISTRIBUTION

The fact that the mite may be distributed from flock to flock by a number of species of wild birds is of considerable importance, the majority of these birds being migratory in nature. Since widespread infestations of this mite have occurred in Canada only during the past few years, it is not unreasonable to believe that the original infestations may have been brought through the migratory birds. All of the birds listed below have been found to carry the mite. These are frequent visitors to the farmyard, and many of them use poultry feathers to line their nests. Infestation may thus be transferred from poultry to young as well as to adult wild birds.

The following table shows the species of wild birds found carrying mites:

Bird	Scientific Name	Infestation	Remarks
Cowbird	*Molothrus ater*	Very light	
Purple Grackle	*Quisculus quiscula*	Heavy	Birds and nests
Robin	*Planesticus migratorius*	Light	
Purple Martin	*Progne subis*	Moderate	
Catbird	*Dumetella carolinensis*	Moderate	Nest. Single record
Starling	*Sturnus vulgaris*	Light	
Hairy Woodpecker	*Dryobates villosus*	Light	Single record
Kingbird	*Tyrannus tyrannus*	Light	Single record
English Sparrow	*Passer domesticus*	Very light	Birds and nests
Barn Swallow	*Hirundo erythrogastra*	Heavy	
Yellow Warbler	*Dendroica aestiva*	Moderate	Single record
Rusty Blackbird	*Euphagus carolinus*	Heavy	Birds and nests
Flicker	*Colaptes auratus*	Light	
Chimney Swift	*Chaetura pelagica*	Light	

The English sparrow is one of the most common birds frequenting poultry plants in this section of the Province of Quebec; yet, only an occasional bird has been found to be infested, and then but slightly. Some

[1] Contribution from the Faculty of Agriculture of McGill University, Macdonald College, Que., Canada. Journal Series No. 69.

[2] Assistant Professor in Poultry Husbandry.

[3] Lecturer in Entomology.

[4] Lecturer in Poultry Husbandry.

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sparrows' nests found in close proximity to purple martin boxes, which are infected every year have been found to contain mites. Payne (*2*) states that he has not found the feather mite on sparrows.

Birds' nests often carry a very heavy infestation, especially those of the purple grackles, rusty blackbirds, and members of the swallow tribe. The first-named seem to be particularly susceptible; in fact, it is the exception to find a bird that is not infested. As many as 800 mites have been found on a well-feathered young grackle taken from a nest containing two other birds. This number is, of course, exceptionally high.

Another means of distribution of the feather mite is the shipping of poultry from infested plants. The authors' experience indicates that this would apply to the transfer of old birds rather than to young stock, since they have had difficulty in artificially infesting the latter. This point, however, requires further investigation.

LIFE HISTORY AND HABITS

No detailed work has been done on the life history of the feather mite, although it is intended that this phase of the project shall be proceeded with in due course.

The mites, which are very active, may be found on all parts of a bird, but the favourite regions are about the vent, in the feathers at the base of the tail, and in the hackle feathers on the neck.

The whitish, oval eggs are deposited among the barbules of the fluff feathers and hatch in a short time into whitish larvae, having only three pairs of legs. Wood (*4*) states that the tropical fowl mite oviposits on birds and inside straws of the nests. Following a moult, the nymphal stage occurs, with the usual four pairs of legs, after which the adults appear. In colour, the adults are darkish brown, which shows some variation, with a distinct colour pattern, which also varies, apparently with age. Cleveland (*1*) believes that the entire life cycle occupies from eight to twelve days. While the authors have no definite information on this point, observations indicate that the life cycle is completed in approximately the time stated.

The mite breeds on the body and among the feathers of its hosts. It may also be found in the nests and on the dropping boards, roosts, and in the cracks in the walls of the poultry house. In these locations it may live for considerable periods after the birds have been removed. The mite's ability to withstand such adverse conditions adds to the difficulty of its control.

Seasonal incidence has been very marked in our work. During the summer, infestation decreases to a marked degree, except on wild birds, and yet, soon after the poultry, apparently free of mites, is placed in its winter quarters, which have been vacant all the summer and thoroughly cleaned and sprayed, infestation becomes very severe. So far, no explanation of this condition is available; some definite information in this regard might be of assistance from the standpoint of control.

In an attempt to study various methods of control adult male stock was kept heavily infested as long during the spring and summer season as was possible, but eventually during the early summer the mites disappeared and could not be found in the house or litter in the coops. The mites,

FIGURE 1. Heavy infestation of northern fowl mite on young purple grackle.

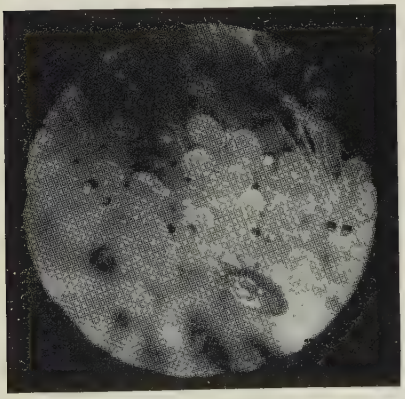

FIGURE 2. Eggs of the northern fowl mite.

however, must have been aestivating in the houses, since they reappeared in the fall season and attacked clean mature male stock when placed in the same house. Leghorn cockerels, about twelve weeks of age, were used for experimental artificial infestations during the midsummer season. Large numbers of the mites were transferred from the infested adult stock and placed directly into the plumage of the young cockerels, and on the roosting boards and floor of the house. The mites did not remain on the young cockerels, and were not to be found in the house during the growing season.

ECONOMIC SIGNIFICANCE

Since the mite attacks young chicks, as reported by Payne (*2*), considerable loss would be incurred through mortality, although probably heavier losses are caused by the infestations on mature stock through greatly reduced vitality, loss of egg production, and breeding activity with male stock. Through careful checking of the infestations of adult stock it has been definitely found that the males are generally carrying heavier infestations, and it is not uncommon to find but few mites on the females in a pen, whereas the male has a very heavy infestation. A further source of loss is that with market male stock to be dressed as meat where abrasions of the skin are caused. Under Canadian conditions, however, this type of damage to the skin of the bird, especially on the back or wing joints and the tail head, rarely occurs until the late fall and early winter season. Infestations on laying pullet stock very seldom occur until after the breeding season has commenced. Such conditions make for more difficult control owing to cold weather, when the treatment is less effective than during the warm weather.

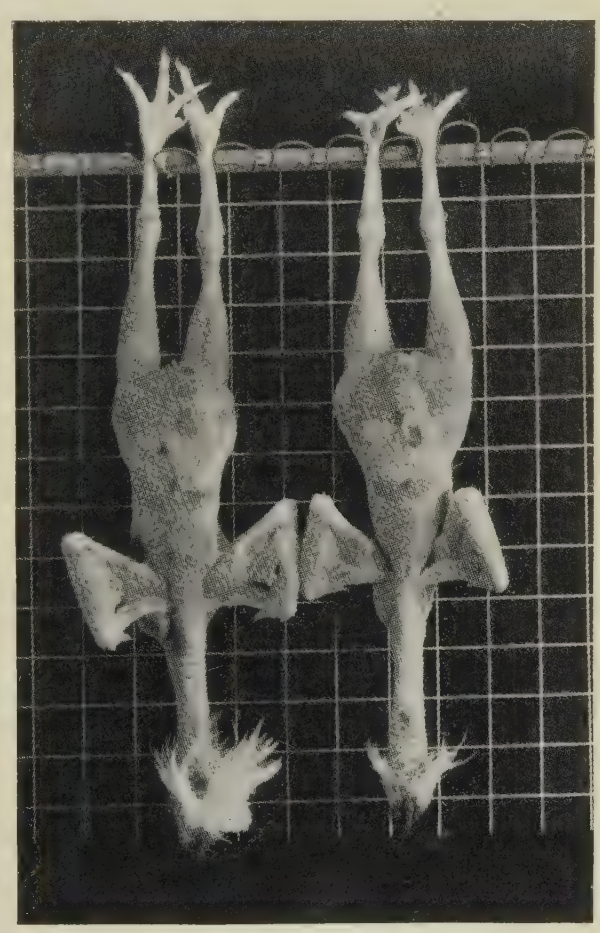

FIGURE 3. Skin abrasions caused by the northern fowl mite.

CONTROL

On Birds

Experimental trials by the authors (*3*) with control products in the form of ointments have been developed with considerable success. A satisfactory ointment for direct application to the body of the bird, or on the roosts, is a mixture of naphthalene flakes, one part, and vaseline, two parts. It is best to grind up the naphthalene in order to facilitate mixing and application, and then stir it into the vaseline. The ointment should be applied in the areas of the tail and vent. During the cold weather conditions, paradichlorobenzene and vaseline in the same proportions is more effective than the naphthalene mixture, due to its greater volatility. It costs more, however, and tends to liquify the vaseline, which makes its application rather more difficult. Sulphur dusts have also been used with fair results.

Laboratory Tests

In order to ascertain the effectiveness of various materials for use in controlling the northern fowl mite in colony houses and pens, a number of preliminary tests were made in the laboratory. The mites were sprayed with an atomizer, allowed to remain for five minutes, before being transferred to a dry vial which was loosely plugged with cotton wool, the counts being made 24 hours later. The action of many of these sprays was almost instantaneous in killing the mites.

TABLE 1.—EFFECT OF DIRECT CONTACT SPRAYS ON NORTHERN FOWL MITE

Material		No. of mites used	% killed	Material		No. of mites used	% killed
Straitar	10%	65	100	Scalecide, Dormant	1–15	148	100
	5%	106	100		1–30	154	100
	2½	112	100				
				Scalecide,			
Tar-O-Wash	10%	65	100	Summer	1–100	156	44.2
	5%	115	100		2½–100	174	74.9
	2½	108	89.1		5–100	138	100
83% Tar Oil							
Emulsion	10%	65	100	Sulfocide	1–150	136	42.7
	5%	127	100		1–100	161	100
	2½	123	100				
				Tarzol	5%	156	100
					2½	134	100
Palustrex sulfonate	1–50	128	100	Barko	1–10	127	100
					1–20	148	100
Palustrex sulfonate							
B.L. 40⅜ pt.	1–50	116	100	Ortho Tar Oil			
				Emulsion	5%	98	100
Emulsion (Crustal					2½	135	100
Soap and Chem.							
Co.)	5%	128	100	Kleen-up Tar			
	2½	59	75.6	Emulsion	5%	138	100
					2½	150	100
Tar E. Mul.	5%	114	100				
	2½	47	100	Water	–	136	6.6
Black Leaf 40							
1 pt. to 100 gals.		127	76.4				

Water was used as a check in order to find out if mechanical action had any effect on the mortality, but as will be seen by the following table, this played a very minor part. It had already been noted that this mite is apparently very resistant to water, more so than some phytophagous species. After being immersed in it for several minutes and then removed, they invariably continued their activities with no apparent ill effects.

The tests in Table 1 were conducted in duplicate with an interval of a fortnight between them. The numbers of mites used in the two series are totalled. The figure in the column "per cent killed" is the average.

The correction for the mortality in the checks has been applied to the results in the treated lots by means of the usual formula, viz., $b - a \times \frac{100}{100-a}$, ($a$ = killed in check; b = killed in treated).

The results given in the foregoing table indicate that practically all the materials used are effective in controlling the mite. These tests, however, were conducted under ideal conditions, the mites having no protection of any kind, so that it was an easy matter to cover them with spray.

Further tests were made under more natural conditions. The mites were placed among sawdust and shavings, similar to those used in the poultry pens and treated with materials as indicated in Table 2.

TABLE 2.—EFFECT OF SPRAYING LITTER FOR CONTROL OF NORTHERN FOWL MITE

Material		No. of mites used	% killed	Material		No. of mites used	% killed
Straitar	5%	155	100	Tar-E-Mul	5%	134	100
	2½	162	100		2½	177	100
Tar-O-Wash	5%	126	100	Emulsion (Crystal Soap and Chemical Co.)	5%	172	100
	2½	147	100		2½	156	100
83% Tar Oil Emulsion	5%	152	100				
	2½	154	96.6	Black Leaf 40 1 pt.–100 gals.		144	69.6
Palustrex Sulfonate 1–50		142	93.4	Water	–	182	6.2

In order that control under these conditions may be satisfactory, a good drenching spray should be applied in order to penetrate the litter. Where the litter is deep, it should be raked over thoroughly and another lighter application made, which either exposes the mites, or brings them into contact with spray already applied. The deeper the litter, the more thorough must be the treatment. These preliminary tests indicate that it is a practical method of keeping down the mite infestation.

Comment on the toxicity of the materials mentioned in the preceding tables is unnecessary. While there is little to choose between them with regard to ease of application and rapidity in killing, it might be noted that while Scalecide (summer) used as a 5% solution killed 100%, it was slow in its action and it was necessary to apply an unusually heavy application. Black Leaf 40 in the strength indicated was also very much slower in killing the mites. These two materials, however, are hardly those that would be recommended for control work of this nature.

Tests in Poultry Pens

Individual cockerel pens, from which birds had been removed three weeks previously, were selected for the following tests. Litter was first obtained from the pens and in each instance it was found to be infested with mites. The pens were then thoroughly sprayed, in duplicate, with the following materials, the litter being raked over during the process. After 48 hours the litter was carefully examined, the results being as follows:—

83% Tar Oil Emulsion

5%	No mites
10%	No mites

Tarocide "B"

5%	No mites
10%	No mites

Check
Infestation unchanged

From the above results it will be seen, that, providing thorough applications are made, both materials are effective in controlling mites under commercial conditions, although further work is necessary before recommendations can be made.

Economically the northern fowl mite is more serious than the ordinary red mite, because it remains on the body of the fowl continually, thereby being easily transferable from one farm to another, and hence, more difficult to control. With the suggested products for treatment of stock and equipment, however, the infestations may be kept in check with considerable ease.

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THE INHERITANCE OF SKELETAL DIMENSIONS IN THE DOMESTIC FOWL[1,2]

A. J. G. MAW[3]

INTRODUCTION

Considerable work has been done with plants and animals concerning the nature of the factors responsible for size. In general it may be said that the results to date have established fully that size is inherited, but the detailed facts required by both the geneticist and the practical breeder have not yet been obtained. The geneticist has still the problem of explaining precisely the manner by which size, a complex character easily influenced by the environment, is inherited. The importance of securing this information need not be amplified. It is sufficient to point out that in our domestic animals economic considerations are making necessary a close study of the relative efficiency of the various breeds and of the individuals within the breeds. Suitability of the size of the animal to the object of production is one of the first steps. In the past, practical breeders reached this end by selective breeding over a long period of years. A knowledge of the genetic principles underlying such breeding operations would allow the breeder to avoid mistakes and to reach the desired end in a shorter time.

In the domestic fowl the solution of the problems involved in the inheritance of size is of considerable economic importance. Poultry meat and eggs now occupy a prominent place in the modern diet. It is obvious that size of body, in a large measure, determines the total amount of edible flesh, and there is good evidence that size of egg is closely related to body size. The attaining of a more economic meat-producing bird and of a general increase in the average weight of eggs may be brought nearer by a more exact knowledge of the inheritance of size and its relationship to other characteristics of the fowl. As a contribution in this direction, an investigation was started to study the inheritance of size by crossing two breeds of fowl widely separated as to size.

PROBLEMS INVOLVED IN SIZE INHERITANCE

The results of most investigations of size have indicated that dominance is apparently lacking. The inheritance is of a blending type, the F_1 mean being at or near an intermediate position between the parental means, and the F_2 forming a graded series whose limits approach the parental types. There are, however, a number of instances in which the size of the individual as a whole or of a particular part is apparently determined by a single gene. "Dwarf" in mice (Snell, *31*), a similar dwarf mutation in the rat (Lambert and Sciuchetti, *17*), the classic case of "tall and short peas" studied by Mendel, and the "creeper" condition in the fowl (Cutler, *5*) are examples of this type of size inheritance. These cases show a dominance of one character over the other and a clear-cut segregation into classes in the second generation. The question arises as to whether or not the inheritance is Mendelian in those cases in which the F_2 population cannot

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[2] Contribution from the Department of Poultry Husbandry, Macdonald College. Macdonald College Journal Series No. 000. Received for publication September 24, 1935.
[3] Lecturer in Poultry Husbandry, Macdonald College.

be segregated into clear-cut classes. Nilsson-Ehle (*23*) developed the multiple-factor hypothesis to explain this type of inheritance. It is based on the assumption that several independent genes lacking dominance which are cumulative in their action are responsible for the size attained. The action of such genes would give an F_1 intermediate in size. A marked increase in variability in the F_2 generation over the parents, or F_1 generation, is taken as evidence of segregation. This does not necessarily mean the reappearance of the parental types in the F_2 generation because of the improbability of such an occurrence, where a number of genes are involved, unless a very large population is obtained. The fact is now generally accepted that in the majority of cases the difference between large and small size is determined by a number of genes.

Phillips (*25*) reported the results of crosses between Rouen and Mallard ducks in which the variability of the F_2 generation was much greater than that of the F_1. The results secured in other experiments such as those of Macdowell (*21*), Punnett and Bailey (*28*), Castle (*2*), and Pease (*24*) with rabbits, and Punnett and Bailey (*27*), Kopec (*16*), Jull and Quinn (*15*), and Waters (*36*) with fowls have indicated that many genes are probably involved. In practically all of these studies the F_1 progenies have been intermediate between the parents in size, and the variability has been greater in the F_2 than in the F_1.

A much debated problem is whether the genes affect the body as a whole or its separate parts. Davenport (*6*) found evidence that the lengths of the parts of the body determining stature in man are to some extent inherited independently. Castle (*3*) found that the correlations between five skeletal measurements in rabbits were uniformly high, and expressed the view that the factors which determine size are general factors affecting all parts of the skeleton simultaneously. Sumner (*32*), on the other hand, found evidence for local size factors in Peromyscus. Wright (*37*) analysed the data of Castle (*2*) and Dunn (*7*) and found that while the influence of general factors is largely responsible for size, there is evidence of the presence of group and special factors. That a similar situation exists in mice was shown by Green (*11*), who found that femur and tibia bones are largely influenced by common factors.

The existence of linkage between size and a qualitative character such as a colour, whose manner of inheritance is well established, has until recently been unknown. Lindstrom (*20*) refers to early work in plants in which there was some evidence of linkage between colour and size, and in a study of several crosses found that two genes for fruit colour were linked with genes for fruit size in tomatoes. It should be noted that the character studied in these cases refers to the size of a particular part of the plant and not to the size of the plant as a whole. The majority of the work on animals differs in this respect, since usually the size of the whole individual is judged by a single criterion such as weight, or by several measurements such as bone lengths, each of which contributes to the total size of the animal. Castle (*4*), mating large rabbits having four dominant genes determining coat colour, each on a different linkage system, with small rabbits carrying the corresponding recessive genes, found no evidence of any linkage between colour and size. The first case of this type of linkage in animals was reported by Green (*12*). Green observed in the back-cross

generation of a cross involving large and small races of mice a significant "association between factors productive of large size in several quantitative characters and a recessive qualitative character, brown coat colour." It would appear that special size factors exist in mice and that these are Mendelian in their behaviour.

A number of studies have been made on birds concerning the factors responsible for the inheritance of size. The domestic breeds of the fowl include examples which differ widely in body size. The early reports of crosses made between breeds differing in size, Ghigi (*8*), Goldschmidt (*9*) and Phillips (*25*, *26*) provided very little information on size inheritance.

A more extensive study was reported by Punnett and Bailey (*27*). These workers crossed a Gold-pencilled Hamburgh male with Silver Sebright Bantam females. The F_1 birds, in general build and habit, were intermediate between the parental types, but approached the larger parent in body weight more than the smaller parent. Among the F_2 progeny there were birds which were lighter in weight than the Sebright Bantams and birds heavier than the Hamburghs. The testing of the large and small F_2 types showed that in general the large-sized birds gave large-sized progeny and the small birds produced small-sized progeny. From an analysis of the F_2 distribution, Punnett and Bailey concluded that several factors, probably four, were concerned.

May (*22*), using the White Cornish as the large breed and the Silver-spangled Hamburgh as the small breed, reported that the F_1 and F_2 generations from a cross between these two breeds develop at the same rate as the Cornish breed and attain the same weight at ten months. Weight and body form as given by various measurements, and their indices were observed by Kopec (*16*) in crosses between White Leghorns and Buff Orpingtons. The data secured indicated that the separate body measurements are to some extent inherited independently of each other.

Waters (*36*) made a study of the body weight in reciprocal crosses between White Leghorns and Light Brahmas. The F_1 generations from these crosses were approximately intermediate in weight between the parental breeds. The F_2 populations showed significantly a greater variability than the F_1 populations. From the results of F_2 and backcross matings this author observed "that weight in the Brahma-Leghorn cross is dependent chiefly upon two pairs of genes each of which affects the weight of the individual equally and which have cumulative effects."

A cross involving breeds which differ more widely in weight than those used in previous experiments was made by Jull and Quinn (*15*). In this case Rose Comb Bantams and Barred Plymouth Rocks were crossed. The mean weight of the males and females of the F_1 generation was found to be much nearer the mean weight of the Bantam parents than the mean weight of the Plymouth Rock parents. This result suggests the dominance of genes responsible for small size and is contrary to the results secured by Punnett and Bailey and May. There was an increase in the variability of the F_2 over that of the F_1. No extreme large or small types were found in the F_2.

It is evident from the above studies that the facts regarding the inheritance of size in the domestic fowl in so far as it is measured in terms of body weight are not all in agreement. In a general way the evidence

indicates that a number of genes are involved, and that they are probably cumulative in determining the final size of the individual. The size of the F_1 progeny in relation to the size of the parents presents a more varied picture. It is quite probable that the nature of the stock used is responsible in most cases for this situation. Any of the modern breeds of fowl have a considerable variability with respect to size. Without resorting to the building up of special inbred lines, there is little possibility of securing homogeneous stock. The alternative in this situation is the use of breeds which are widely separated as to size and between which there is no overlapping.

In all the above studies on the fowl, body weight was used as the single measure of size, with the exception that Kopec (*16*) observed other measurements which give some indication of body form. Weight is a convenient measure to obtain and permits the use of the bird in further breeding work. However, it is not a constant measure. The bird has a steady increase in weight from hatching until about ten months of age. The weight then remains uniform for six to eight months, when a second increase takes place. It is necessary, therefore, in size inheritance studies that all birds be weighed at the same relative age. Variation in the rate of maturity may influence the results obtained where early weights are taken. Environmental factors, such as temperature and food supply, also contribute largely to the variability in weight. A comparison of the variability of body weight with the variability of bone length of White Leghorns was made by Schneider and Dunn (*30*), who found that the coefficients of variation were 12 to 18% and 3.5 to 4.5%, respectively, for these measurements. It is evident that skeletal dimensions are a much more reliable index of body size than body weight.

The work of this study has been confined to the securing of information concerning the inheritance of skeletal dimensions, and the relation between such measurements and other qualitative characters carried by the breeds which were crossed.

MATERIALS AND METHODS

The data used in this study were obtained from the first and second generation offspring of reciprocal crosses between Light Brahmas and Golden Sebright Bantams. These breeds differ very widely in body size. In fact, they are close to the extremes which have been reached in the breeding of the domestic fowl for large and small size. The standard weights of these breeds are as follows: Light Brahma, cock 12 lbs. (5434 gms.), cockerel 10 lbs. (4528 gms.), hen $9\frac{1}{2}$ lbs. (4302 gms.), pullet 8 lbs. (4075 gms.); Golden Sebright Bantam, cock 26 oz. (736 gms.), cockerel 22 oz. (623 gms.), hen 22 oz. (623 gms.), pullet 20 oz. (566 gms.). The Light Brahmas used were on the average considerably below standard weight, while the Sebrights were slightly above standard weight.

In order to make a cross between these two breeds, it was necessary to resort to artificial insemination. Seminal fluid was obtained from the male birds by interposing a watch glass between the male and a female at the time of mating. The seminal fluid, slightly diluted with saline solution, was then transferred to the cloaca of the females. Parental crosses were made between a Sebright Bantam male and four Brahma females, and between a Brahma male and eight Sebright Bantam females.

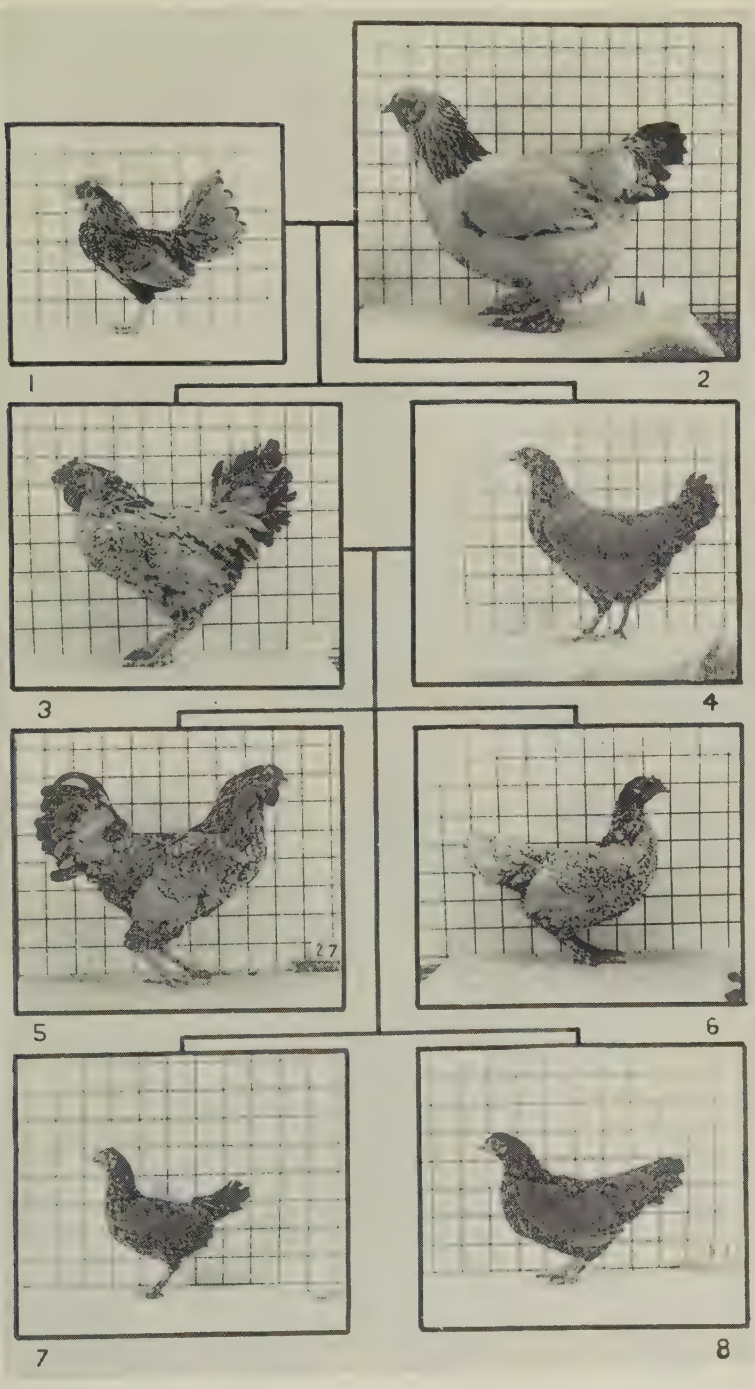

PLATE I. 1. Golden Sebright Bantam male; 2. Light Brahma female; 3. F_1 male (silver); 4. F_1 female (gold); 5. F_2 male (silver, large); 6. F_2 female (silver, intermediate); 7. F_2 male (gold, small); 8. F_2 female (gold, small).

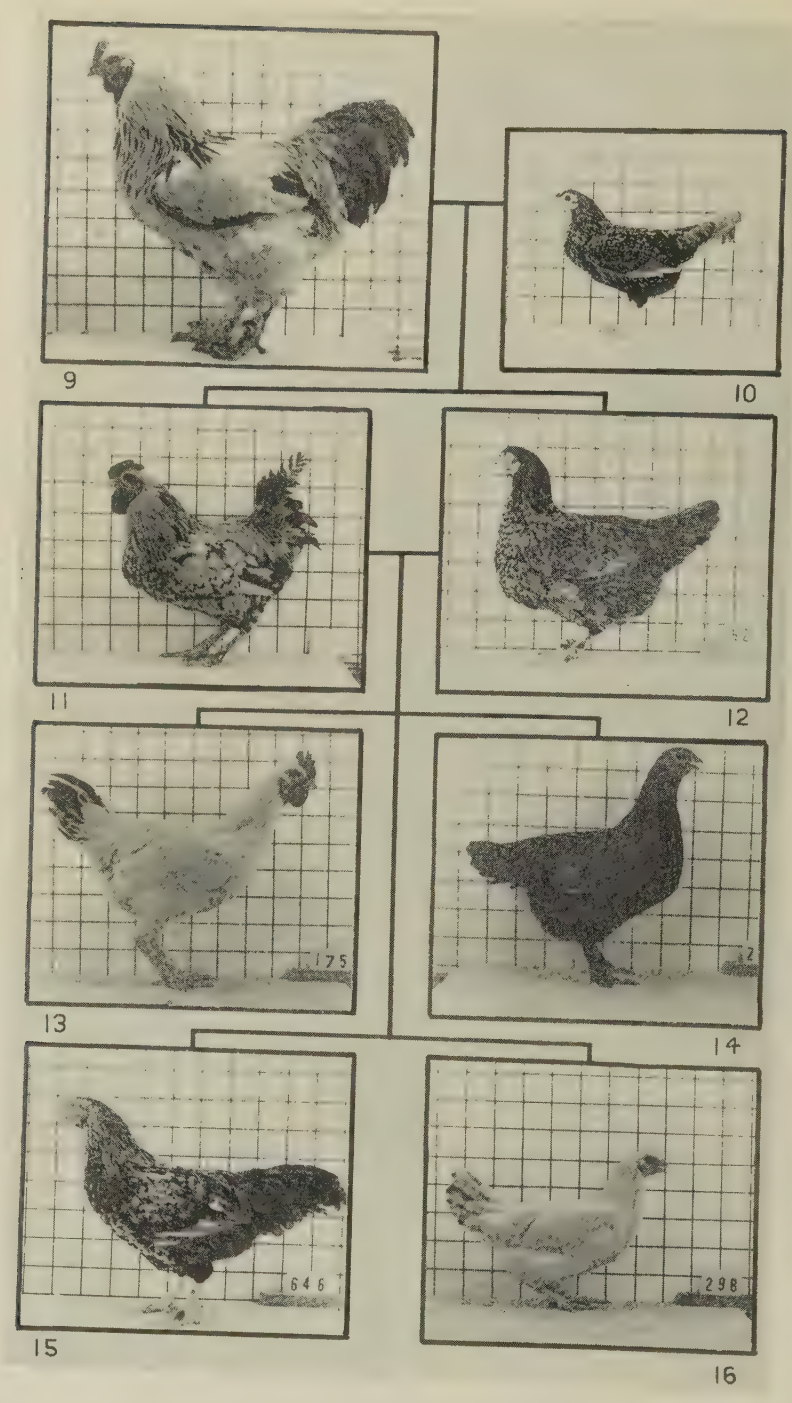

PLATE II. 9. Light Brahma male; 10. Golden Sebright Bantam female; 11. F_1 male (silver); 12. F_1 female (silver); 13. F_2 male (silver, large); 14. F_2 female (gold, large); 15. F_2 male (silver, intermediate); 16. F_2 female (silver, small).

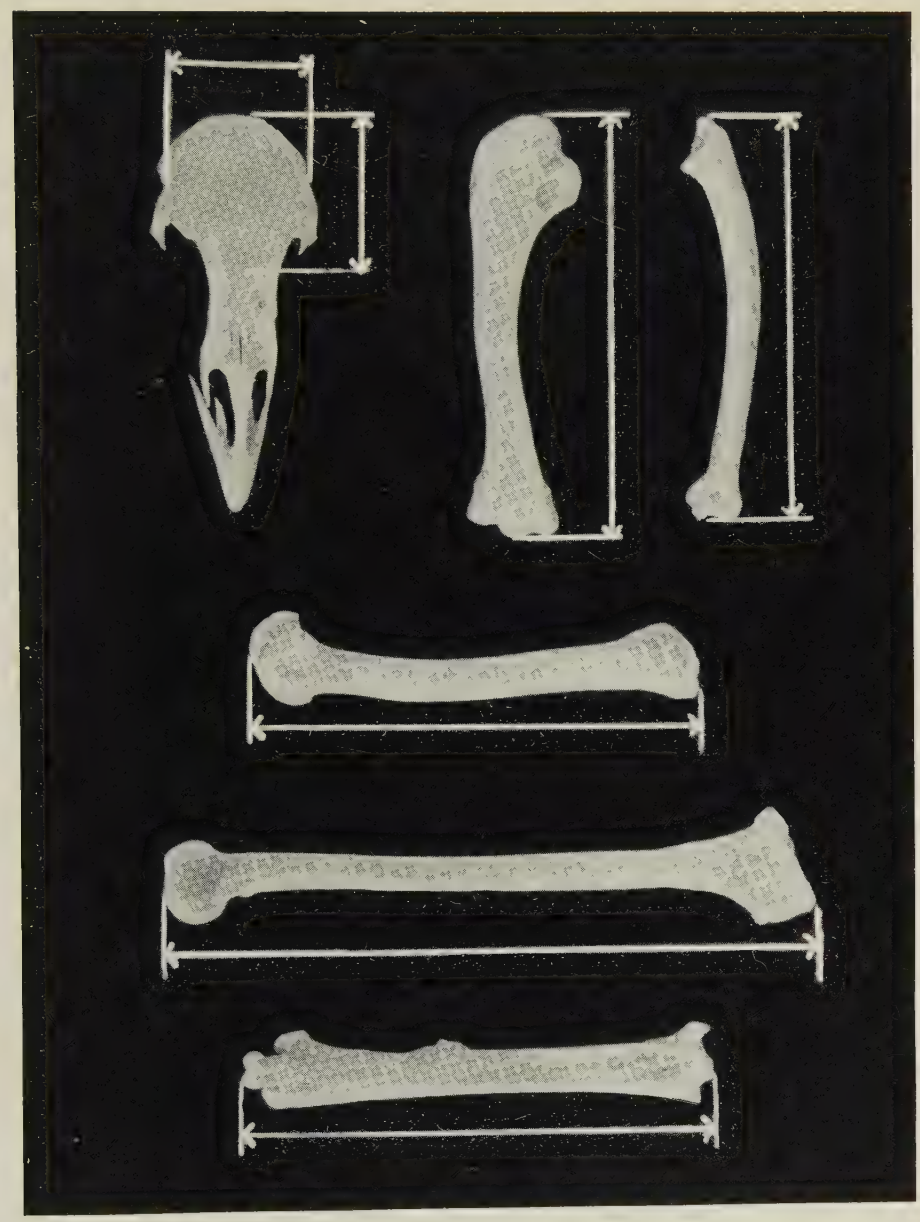

PLATE III. Showing the points at which the measurements were taken on the various bones.

Considerable difficulty was experienced in obtaining fertility. While artificial insemination permits the crossing of breeds which are unable to mate naturally, the results of the method vary widely. The high percentage of infertile eggs reduces very materially the number of progeny obtained. From the cross of a Golden Sebright Bantam male with Light Brahma females, an F_1 progeny of 13 males and 14 females was obtained. Three matings of F_1 individuals produced an F_2 population of 228 males and 262 females. The reciprocal cross of a Light Brahma male with Golden Sebright Bantam females gave an F_1 progeny of 15 males and 9 females. The F_2 generation from two matings of these F_1 individuals consisted of 31 males and 39 females. These figures include all chicks hatched from which some data were secured. For the purpose of checking the inheritance of plumage colour and other characters which could be identified easily, all fully developed dead embryos were examined.

All birds were grown under as uniform conditions as possible. Methods of management and the rations fed varied very little. It was found necessary to continue hatching throughout the year, so provision was made to rear the birds in batteries in a well-controlled brooder room. Under these conditions good growth was made during the rearing period. The birds kept after eight months of age were placed in small pens in a heated building. An outbreak of infectious bronchitis occurred in the F_2 population which caused a considerable number of deaths. The skeletons of all birds over six months of age which died or were killed were saved for measuring.

Schneider and Dunn (*30*) and Latimer (*18*) have shown that bone growth ceases early in the domestic fowl. The former found no changes in the bone length of White Leghorns after 160 days. It is likely that this point of time varies according to the breed. The Brahma is a slow-growing bird, and in order to obtain maturity in bone length the birds selected in this breed were all over ten months of age. All the other birds whose skeletons were saved had reached 180 days of age. The majority were over 250 days old when killed, with an average of 364 days.

The skeletal measurements considered are the following: the absolute lengths of the femur, tibio-tarsus, tarso-metatarsus, humerus, ulna; cranial length and cranial breadth. The bones were prepared by boiling in a solution of water, ammonia, phenol and soap until the flesh could be easily removed. They were then left at room temperature until completely dry. The measurements were made to the nearest half millimetre in the case of the leg and wing bones and to the nearest tenth millimetre for the cranial dimensions. The same points on each bone were always used for measurement. These are shown in Plate III and were as follows:

Femur—from the proximal extremity of the trochanter major to the end of the external condyle.

Tibio-tarsus—from the end of the cnemial process to the farthest point of the external condyle.

Tarso-metatarsus—from the extremity of the ridge between the surfaces on which the tibio-tarsal condyles articulate to the end of the middle trochlea.

Humerus—from the farthest point of the proximal head to the end of the ulnar trochlea.

Ulna—from the extremity of the olecranon to the distal end of the trochlear surface.

Cranial length—from the most anterior part of fusion of the frontal bones to the most posterior point of the occipital.

Cranial breadth—the distance between the deepest point of the slight concavities on the anterior part of the temporal bones.

The Light Brahma and the Golden Sebright Bantam differ in respect to a number of characters the inheritance of which has been previously reported on. Descriptions were taken of these characters as displayed by the offspring secured from the various matings. The characters noted were: comb type, plumage colour, rate of tail feathering, shank colour, presence or absence of feathers on the legs and brachydactylism. In so far as possible, these characters have been analysed for linkage with the skeletal measurements.

In the statistical analysis, the methods of Wallace and Snedecor (*34*) have, in general, been used. The errors given for the various constants are standard errors. The F_1 as a percentage of the mean parental difference is based on the difference of the means of the same sex in the contrasted breeds.

BODY WEIGHT

Although body weight has not been taken as the criterion of size, the body weight constants are presented in Table 1 in order that a comparison may be made of the weight of the birds from which the skeletal dimensions were obtained with the weight of the birds on which other investigations

TABLE 1.—BIOMETRIC CONSTANTS OF BODY WEIGHTS OF THE PARENTAL, F_1 AND F_2 MALES AND FEMALES, RESPECTIVELY, IN THE RECIPROCAL CROSSES BETWEEN LIGHT BRAHMAS AND GOLDEN SEBRIGHT BANTAMS*

Breed	Sex	No.	Mean (gms.)	Standard deviation (gms.)	Coefficient of variability (per cent)
Brahma	♂ ♂	9	3998.89 ± 75.51	226.54 ± 53.40	5.66 ± 1.34
	♀ ♀	22	3101.82 ± 89.62	420.36 ± 63.37	13.55 ± 2.06
Sebright	♂ ♂	6	815.50 ± 47.76	121.86 ± 35.18	5.07 ± 1.47
	♀ ♀	16	600.87 ± 23.46	93.84 ± 16.59	15.62 ± 2.83
F_1 (S×B)	♂ ♂	9	1813.44 ± 86.38	259.15 ± 61.09	14.29 ± 3.43
	♀ ♀	7	1410.71 ± 43.22	114.31 ± 30.55	8.10 ± 2.18
F_1 (B×S)	♂ ♂	5	2077.00 ± 157.77	352.78 ± 111.57	16.98 ± 5.52
	♀ ♀	4	1495.00 ± 134.47	268.93 ± 95.09	17.99 ± 6.56
F_2 (S×B) (S×B)	♂ ♂	82	1277.12 ± 34.30	284.94 ± 21.36	22.31 ± 1.75
	♀ ♀	69	1225.13 ± 31.26	259.71 ± 19.47	21.20 ± 1.66
F_2 (B×S) (B×S)	♂ ♂	8	1650.00 ± 106.11	300.07 ± 75.01	18.19 ± 4.69
	♀ ♀	21	1256.90 ± 56.04	256.78 ± 39.62	20.43 ± 3.28
Brahma-Sebright Midweight values	♂ ♂		2407.19		
	♀ ♀		1851.35		

*The data given in this table represent the body weights of the F_1 and F_2 males and females at eight months of age. The body weights of the Brahma and Sebright males and females were obtained at various ages. The majority of the birds were over twelve months of age.

of the inheritance of size have been carried out. The Light Brahma males and females weighed approximately 500 grams less than the standard weight for the breed. The Golden Sebright Bantam males were about 200 grams above standard weight, while the females were very close to standard weight. The majority of crosses made between the breeds of fowl, for the purpose of studying size inheritance, have been made between breeds whose mean weights were not as widely separated as those used in this work. One exception is the cross made by Jull and Quinn (*15*) between Barred Plymouth Rocks and Rose-Comb Black Bantams. The mean weights of the birds of these breeds are close to those of the Light Brahmas and Golden Sebright Bantams. The Light Brahma males weighed about 500 grams more than the Barred Plymouth Rock males used by Jull and Quinn.

The mean weights of the F_1 birds from the reciprocal crosses were not intermediate between the parental weights. There appears to be a tendency for the F_1 mean weight to approach the mean weight of the smaller parent. This is in agreement with the results of Jull and Quinn, who state that "the relative size of the F_1 progeny in the reciprocal crosses suggests that there is dominance or partial dominance of one or more factors associated with the inheritance of body weight in Rose-Comb Black Bantams over the factors associated with the inheritance of body weight in Barred Plymouth Rocks." The data in Table 1 indicate that a similar condition exists in the Brahma-Sebright cross. The F_2 progeny also tended, on the average, to be small. As will be shown later in considering the skeletal dimensions, there were obtained in the F_2 generation some birds as small as the Sebright Bantams, but no individuals as large as the average Brahmas. However, it should be pointed out that body weight has a high coefficient of variability, and, assuming that a considerable number of factors are involved in its inheritance, a much larger population might give different results.

The coefficient of variability of body weight for all the groups in this study was approximately 15%. The number of birds involved is too small to admit a comparison of the different groups, except to note that the F_2 progenies were slightly more variable than the other groups.

SKELETAL DIMENSIONS

(a) Mean Bone Measurements

The data concerning the absolute lengths of the bones of the appendicular skeleton, cranial length and cranial breadth are given in Table 2. A comparison of the means of the parental breeds shows relatively large differences in these dimensions. The ratio of the leg and wing bones of the Golden Sebright Bantams to those of the Light Brahmas is approximately as 1 to 1.7. The ratios for cranial length and cranial breadth are of the order of 1 to 1.5 and 1 to 1.3, respectively. There is no difference between the sexes with respect to the size of the ratios. The data are given in Table 2 for femur length and cranial length are presented graphically in Figures 17 and 18. These distributions show clearly the wide spread between the means of the parental breeds. The figures also give some indication of the range of each parental group.

The mean measurements of the F_1 birds from the reciprocal crosses appear from the data of Table 2 to occupy an intermediate position. A

TABLE 2.—MEANS AND VARIATION CONSTANTS OF SKELETAL MEASUREMENTS

Group	Sex	No.	Mean (mm.)	Standard deviation (mm.)	Coefficient of variability (per cent)
			Femur		
Light Brahma	♂ ♂	9	113.500±1.145	3.439±0.811	3.030±0.714
	♀ ♀	18	96.903±0.707	3.002±0.500	3.098±0.516
Golden Sebright	♂ ♂	6	64.875±1.857	4.550±1.313	7.013±2.024
	♀ ♀	16	57.063±0.714	2.859±0.505	5.010±0.885
F_1 (S×B)	♂ ♂	10	87.300±0.756	2.391±0.535	2.738±0.612
	♀ ♀	7	71.178±1.221	3.231±0.863	4.539±1.213
F_1 (B×S)	♂ ♂	9	85.639±1.138	4.728±1.114	5.520±1.301
	♀ ♀	4	79.687±2.394	4.788±1.693	6.008±2.124
F_2 (S×B) (S×B)	♂ ♂	89	79.974±0.602	5.680±0.426	7.102±0.532
	♀ ♀	83	70.834±0.616	5.613±0.436	7.924±0.615
F_2 (B×S) (B×S)	♂ ♂	8	93.375±1.463	4.138±1.034	4.431±1.108
	♀ ♀	22	76.102±0.908	4.263±0.643	5.601±0.844
			Tibio-tarsus		
Light Brahma	♂ ♂	9	167.778±1.425	4.301±1.013	2.563±0.604
	♀ ♀	18	139.403±0.888	3.770±0.628	2.704±0.450
Golden Sebright	♂ ♂	6	91.917±2.489	6.097±1.760	6.633±1.914
	♀ ♀	16	81.156±0.969	3.876±0.685	4.776±0.844
F_1 (S×B)	♂ ♂	10	126.950±1.464	4.631±1.035	3.647±0.815
	♀ ♀	7	102.893±1.493	3.950±1.056	3.839±1.026
F_1 (B×S)	♂ ♂	9	124.194±2.863	8.591±2.025	6.917±1.630
	♀ ♀	4	113.500±3.340	6.680±2.362	5.885±2.080
F_2 (S×B) (S×B)	♂ ♂	89	114.536±0.903	8.519±0.638	7.437±0.557
	♀ ♀	83	100.081±0.861	7.850±0.609	7.844±0.609
F_2 (B×S) (B×S)	♂ ♂	8	136.438±2.663	7.531±1.883	5.531±1.383
	♀ ♀	22	108.853±1.232	5.777±0.871	5.307±0.800
			Tarso-metatarsus		
Light Brahma	♂ ♂	9	116.112±1.164	3.494±0.823	3.009±0.709
	♀ ♀	18	93.597±0.849	3.603±0.600	3.849±0.641
Golden Sebright	♂ ♂	6	61.000±1.424	3.489±1.007	5.719±1.650
	♀ ♀	16	52.891±0.849	3.397±0.600	6.422±1.135
F_1 (S×B)	♂ ♂	10	85.625±1.162	3.677±0.822	4.294±0.960
	♀ ♀	7	67.929±0.791	2.094±0.560	3.082±0.824
F_1 (B×S)	♂ ♂	9	83.167±2.364	7.094±1.672	8.529±2.010
	♀ ♀	4	74.562±1.790	3.581±1.266	4.803±1.698
F_2 (S×B) (S×B)	♂ ♂	89	78.946±0.674	6.359±0.476	8.055±0.604
	♀ ♀	83	66.671±0.589	5.369±0.417	8.053±0.625
F_2 (B×S) (B×S)	♂ ♂	8	91.250±2.075	5.868±1.467	6.340±1.607
	♀ ♀	22	70.613±0.773	3.628±0.546	5.137±0.774

TABLE 2.—MEANS AND VARIATION CONSTANTS OF SKELETAL MEASUREMENTS—*Continued*

Group	Sex	No.	Mean (mm.)	Standard deviation (mm.)	Coefficient of variability (per cent)
			Humerus		
Light Brahma	♂♂	9	102.805±1.126	3.378±0.796	3.286±0.775
	♀♀	18	88.695±0.567	2.408±0.301	2.715±0.352
Golden Sebright	♂♂	6	60.209±1.543	3.781±1.091	6.279±1.812
	♀♀	16	54.359±0.763	3.051±0.539	5.612±0.992
F_1 (S×B)	♂♂	10	79.900±0.773	2.446±0.547	3.061±0.648
	♀♀	7	67.036±0.786	2.080±0.556	3.102±0.829
F_1 (B×S)	♂♂	9	78.667±1.421	4.264±1.005	5.424±1.278
	♀♀	4	73.875±1.416	2.833±1.001	3.834±1.354
F_2 (S×B) (S×B)	♂♂	89	73.958±0.539	5.085±0.381	6.875±0.515
	♀♀	83	66.222±0.516	4.706±0.365	7.106±0.551
F_2 (B×S) (B×S)	♂♂	8	84.782±1.207	3.411±0.853	3.885±0.971
	♀♀	22	70.511±0.662	3.105±0.468	4.403±0.663
			Ulna		
Light Brahma	♂♂	9	101.222±1.021	3.065±0.722	3.027±0.713
	♀♀	18	86.528±0.560	2.379±0.396	2.749±0.358
Golden Sebright	♂♂	6	58.833±1.477	3.619±1.044	6.151±1.775
	♀♀	16	52.141±0.779	3.118±0.551	5.979±1.057
F_1 (S×B)	♂♂	10	78.100±0.719	2.274±0.508	2.911±0.651
	♀♀	7	65.071±1.171	3.098±0.828	4.761±1.272
F_1 (B×S)	♂♂	9	77.528±1.064	4.193±0.988	5.408±1.274
	♀♀	4	72.187±1.856	3.713±1.312	5.143±1.818
F_2 (S×B) (S×B)	♂♂	89	73.227±0.552	5.207±0.390	7.111±0.533
	♀♀	83	65.135±0.544	4.957±0.385	7.610±0.591
F_2 (B×S) (B×S)	♂♂	8	83.906±1.271	3.596±0.899	4.285±1.071
	♀♀	22	69.090±0.662	3.017±0.468	4.497±0.677
			Cranial Length		
Light Brahma	♂♂	9	47.411±0.423	1.271±0.299	2.680±0.632
	♀♀	18	43.514±0.310	1.451±0.219	3.341±0.504
Golden Sebright	♂♂	6	31.417±0.477	1.169±0.337	3.721±1.074
	♀♀	16	29.562±0.298	1.184±0.209	4.005±0.708
F_1 (S×B)	♂♂	10	39.000±0.373	1.180±0.264	3.025±0.676
	♀♀	7	35.929±0.409	1.083±0.289	3.014±0.806
F_1 (B×S)	♂♂	9	38.307±1.065	3.195±0.753	8.340±1.966
	♀♀	4	37.250±0.544	1.089±0.385	2.923±1.033
F_2 (S×B) (S×B)	♂♂	89	36.280±0.213	2.009±0.150	5.537±0.415
	♀♀	83	34.524±0.197	1.796±0.139	5.202±0.404
F_2 (B×S) (B×S)	♂♂	8	40.812±0.384	1.088±0.272	2.665±0.666
	♀♀	22	36.443±0.287	1.348±0.203	3.698±0.557

TABLE 2.—MEANS AND VARIATION CONSTANTS OF SKELETAL MEASUREMENTS—*Concluded*

Group	Sex	No.	Mean (mm.)	Standard deviation (mm.)	Coefficient of variability (per cent)
			Cranial Breadth		
Light Brahma	♂♂	9	29.416±0.304	0.913±0.215	3.103±0.731
	♀♀	18	27.181±0.224	0.949±0.158	3.491±0.582
Golden Sebright	♂♂	6	21.041±0.365	0.895±0.258	4.254±1.228
	♀♀	16	19.906±0.165	0.660±0.117	3.315±0.586
F_1 (S×B)	♂♂	10	25.100±0.113	0.531±0.080	2.115±0.318
	♀♀	7	23.322±0.223	0.591±0.158	2.534±0.677
F_1 (B×S)	♂♂	9	24.861±0.406	1.219±0.287	4.903±1.156
	♀♀	4	24.000±0.306	0.612±0.216	2.550±0.902
F_2 (S×B) (S×B)	♂♂	89	23.733±0.112	1.061±0.079	4.470±0.335
	♀♀	83	22.900±0.106	0.966±0.075	4.218±0.327
F_2 (B×S) (B×S)	♂♂	8	25.531±0.355	1.003±0.251	3.928±0.982
	♀♀	22	23.750±0.118	0.555±0.837	2.288±0.344

closer examination of the data brings out the fact that, with the exception of the means of the females from the Brahma male-Sebright female cross, the means are somewhat less than exactly halfway between the parental means. The F_1 means as a percentage of the mean parental difference are given in Table 3. The leg and wing bones of the males from the Sebright-Brahma cross ranged from 44.6 to 46.2% of the parental differences. The same bones of the females, ranging from 35.4 to 37.6%, represent a very much lower percentage of the parental differences. The data from the reciprocal cross show smaller differences between the sexes. The males were slightly below the intermediate position while the females were slightly above. In general appearance the females of the separate groups were quite uniform, but the groups were noticeably different in size and conformation. This visual observation (see photographs of F_1 females, Figures 4 and 12) is substantiated by the bone measurements.

The difference noted with regard to the bones of the appendicular skeleton of the females from the reciprocal crosses is not apparent in the cranial dimensions. The cranial dimensions are approximately 46% of the parental difference. This figure is decidedly different from the 35 to 38% for the leg and wing bones. It would appear that the cranial dimensions are influenced by factors separate from those controlling the size of the bones of the leg and wing. These results suggest the presence of a sex-linked gene for small size of the bones of the appendicular skeleton.

The mean bone measurements of the F_2 progenies show a general tendency to approach the mean of the smaller parent. This is particularly evident in the (S×B) (S×B) cross. The mean bone measurements of the females from this cross were approximately the same as those of the F_1 females while the males were significantly smaller than the F_1 males. In the reciprocal cross the mean bone measurements of the males were significantly larger than the F_1 males and those of the females were slightly smaller than the F_1 females.

TABLE 3.—THE F^1 AS A PERCENTAGE OF THE MEAN PARENTAL DIFFERENCES

—	Sex	Brahma (No. ♂♂ 9) (No. ♀♀ 18) Mean (mm.)	Sebright (No. ♂♂ 6) (No. ♀♀ 16) Mean (mm.)	Midlength values (mm.)	F_1(S×B) (No. ♂♂ 10) (No. ♀♀ 7) Mean (mm.)	$\frac{(F_1 (S\times B) - S) \times 100}{B - S}$	F_1(B×S) (No. ♂♂ 9) (No. ♀♀ 4) Mean (mm.)	$\frac{(F_1 (B\times S) - S) \times 100}{B - S}$
Femur	♂♂	113.500 ± 1.145	64.875 ± 1.857	89.187	87.300 ± 0.756	46.12	85.639 ± 1.138	42.70
	♀♀	96.903 ± 0.707	57.063 ± 0.714	76.563	71.178 ± 1.221	35.43	79.687 ± 2.394	56.79
Tibio-tarsus	♂♂	167.778 ± 1.425	91.917 ± 2.489	129.847	126.950 ± 1.464	46.18	124.194 ± 2.863	42.55
	♀♀	139.403 ± 0.888	81.156 ± 0.969	110.279	102.893 ± 1.493	37.32	113.500 ± 3.340	55.53
Tarso-metatarsus	♂♂	116.112 ± 1.164	61.000 ± 1.424	88.556	85.625 ± 1.162	44.68	83.167 ± 2.364	40.22
	♀♀	93.597 ± 0.849	52.891 ± 0.849	73.244	67.929 ± 0.791	36.94	74.562 ± 1.790	53.24
Humerus	♂♂	102.805 ± 1.126	60.209 ± 1.543	81.507	79.900 ± 0.773	46.23	78.667 ± 1.421	43.33
	♀♀	88.695 ± 0.567	54.359 ± 0.763	71.527	67.036 ± 0.786	36.92	73.875 ± 1.416	56.84
Ulna	♂♂	101.222 ± 1.021	58.833 ± 1.477	80.027	78.100 ± 0.719	45.45	77.528 ± 1.064	44.10
	♀♀	86.528 ± 0.560	52.141 ± 0.779	69.334	65.071 ± 1.171	37.60	72.187 ± 1.856	58.29
Cranial length	♂♂	47.411 ± 0.423	31.417 ± 0.477	39.414	39.000 ± 0.373	47.41	38.307 ± 1.065	43.08
	♀♀	43.514 ± 0.310	29.562 ± 0.298	36.538	35.929 ± 0.409	45.63	37.250 ± 0.544	55.10
Cranial breadth	♂♂	29.416 ± 0.304	21.041 ± 0.365	25.228	25.100 ± 0.113	48.52	24.861 ± 0.406	45.71
	♀♀	27.181 ± 0.224	19.906 ± 0.165	23.543	23.322 ± 0.223	46.95	24.000 ± 0.306	56.27

(b) Sex Dimorphism

The differences between the reciprocal F_1 progenies, when the mean measurements are considered as a percentage of the mean parental difference, are also evident in the sex dimorphism. Table 4 gives the sex differences in mean length and in per cent of the bone dimensions in the parental, F_1 and F_2 generations.

TABLE 4.—SEX DIMORPHISM IN BONE LENGTH

Bone	Group	Difference (mm.)	Difference (per cent)
		(Male-Female)	
Femur	Brahma	16.597 ± 1.346	17.13
	Sebright	7.812 ± 1.989	15.44
	F_1 (S×B)	16.122 ± 1.436	22.65
	F_1 (B×S)	5.952 ± 2.651	7.47
	F_2 (S×B) (S×B)	9.140 ± 0.861	12.90
	F_2 (B×S) (B×S)	17.273 ± 1.722	22.69
Tibio-tarsus	Brahma	28.375 ± 1.679	20.35
	Sebright	10.761 ± 2.670	13.26
	F_1 (S×B)	24.057 ± 2.091	23.38
	F_1 (B×S)	10.694 ± 4.399	9.42
	F_2 (S×B) (S×B)	14.453 ± 1.248	14.44
	F_2 (B×S) (B×S)	27.585 ± 2.934	25.34
Tarso-metatarsus	Brahma	22.515 ± 1.441	24.05
	Sebright	8.109 ± 1.657	15.33
	F_1 (S×B)	17.696 ± 1.405	26.06
	F_1 (B×S)	8.605 ± 2.965	11.55
	F_2 (S×B) (S×B)	12.275 ± 0.895	18.41
	F_2 (B×S) (B×S)	20.637 ± 2.214	29.22
Humerus	Brahma	14.110 ± 1.261	15.91
	Sebright	5.859 ± 1.721	10.76
	F_1 (S×B)	12.864 ± 1.102	19.19
	F_1 (B×S)	4.792 ± 1.422	6.49
	F_2 (S×B) (S×B)	7.736 ± 0.746	11.68
	F_2 (B×S) (B×S)	14.271 ± 1.377	20.24
Ulna	Brahma	14.694 ± 1.164	16.98
	Sebright	6.742 ± 1.669	12.93
	F_1 (S×B)	13.029 ± 1.374	20.02
	F_1 (B×S)	5.341 ± 2.139	7.40
	F_2 (S×B) (S×B)	8.092 ± 0.775	12.42
	F_2 (B×S) (B×S)	14.816 ± 1.433	21.44
Cranial length	Brahma	3.897 ± 0.524	8.95
	Sebright	1.855 ± 0.562	6.27
	F_1 (S×B)	3.071 ± 0.553	8.54
	F_1 (B×S)	1.057 ± 1.196	2.84
	F_2 (S×B) (S×B)	1.756 ± 0.290	5.09
	F_2 (B×S) (B×S)	4.369 ± 0.479	11.99
Cranial breadth	Brahma	2.235 ± 0.377	8.22
	Sebright	1.135 ± 0.400	5.70
	F_1 (S×B)	1.778 ± 0.250	7.62
	F_1 (B×S)	0.861 ± 0.650	3.59
	F_2 (S×B) (S×B)	0.833 ± 0.154	3.64
	F_2 (B×S) (B×S)	1.781 ± 0.374	7.49

The mean values of the males are significantly greater than those of the females except in the case of the cranial measurements of the F_1 (S×B) group. The groups show considerable variation when the difference is expressed on a percentage basis. Hutt (*14*) measured the humerus, ulna, femur and tibio-tarsus bones of White Leghorn males and females and found that the male bones were 13.4% longer on the average than the female bones. The same worker using the data of Latimer found a difference of 15.6%. Schneider and Dunn (*30*) found a difference of 16% in White Leghorns. Considering the same bones as were measured by the above workers, the data of this study show that the male bones exceed the female bones in length by the following percentages: Brahmas, 17.5%; Sebrights, 13%; F_1 (S×B) group, 21.3%; and the F_1 (B×S) group 7.7%. It is evident that the Brahmas and Sebrights used in this study were not greatly different in sex dimorphism from the other breeds that have been reported on. The F_1 progenies, however, show a wide deviation from the parental percentages. The F_1 (B×S) group, having a small number of relatively large females, had a low sex-dimorphism percentage. The reciprocal F_1 (S×B) group shows a greater per cent difference than the larger parent. In the F_2 generation the progeny of the (B×S) (B×S) cross also had a large sex difference. The increase shown by these groups of 5 to 6% over that which might be taken as the approximate normal sex dimorphism supports the suggestion that special factors caused a reduction in the bone dimensions of the F_1 (S×B) females.

(c) Variability

One of the consequences of the multiple-factor theory of size inheritance is that the F_2 show an increased variability over that of the F_1. The studies of the inheritance of body weight in the domestic fowl have shown, with the exception of the results given by May (*22*), an increase in variability in the F_2 population. The coefficients of variability of the bone measurements are given in Table 2. The range of the coefficient of variability of body weight as given by several investigators is from 10 to 18%. The fact that bone lengths are much more stable characters than body weight was pointed out by Schneider and Dunn (*30*). These workers found coefficients of variability of bone lengths from 3.5 to 4.5%, while Hutt (*14*) reported slightly higher figures. In this study the coefficients of variability of both the Light Brahmas and the Golden Sebright Bantams are somewhat greater, but in no case higher than 9%. The coefficients of variability of the bone dimensions for the other groups show no significannt change between the F_1 and F_2 generations. The coefficients of the F_2 groups are, in most cases, larger than those of the F_1 for the same bone, but little reliance can be placed on such slight differences.

Hutt (*14*) found the tarso-metatarsus to be relatively more variable than any other bone in the appendicular skeleton. There is a slight indication in this material that the tarso-metatarsus is more variable than the other bones, but apart from this no single leg or wing bone appears to vary more than any other one. The cranial dimensions, on the other hand, are, in some groups, less variable than the leg and wing bones. A similar finding was reported by Schneider and Dunn (*30*), and it would appear that cranial dimensions are relatively less variable than the bones of the appendicular skeleton. The lack of uniformity in the coefficients

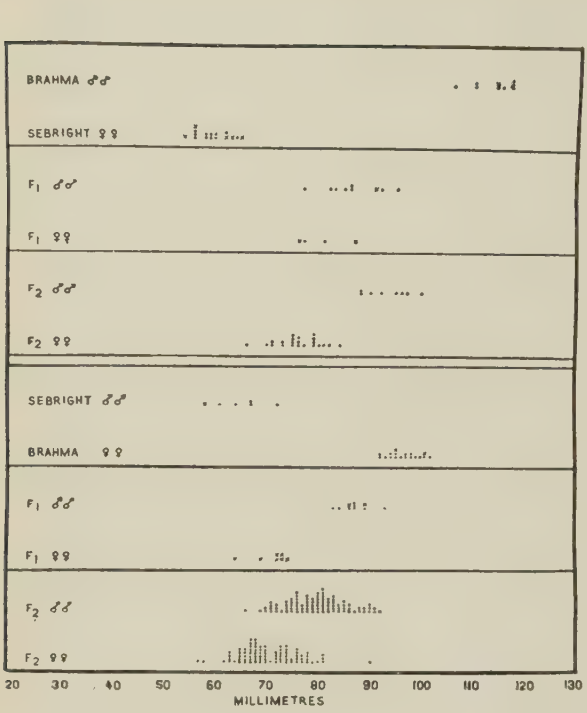

FIGURE 17. Showing the distribution of femur length in parental, F_1 and F_2 generations.

of variability, and the absence of a significant increase from the F_1 to the F_2 makes this constant in this study of little value in determining the facts of the inheritance of skeletal dimensions. It is impossible to determine whether this is due to the small numbers involved or to the heterogeneity of the stock.

An examination of the frequency distributions (Figures 17 and 18) shows that the range of the F_2 progenies, particularly that from the Sebright-Brahma cross, is much greater than the F_1. No individuals as large as the largest parent or smaller than the smallest parent were obtained. No males were secured as large as even the smallest Brahma male. Small males in the Sebright range were found. Large F_2 females in the Brahma range and small females in the Sebright range were obtained. As pointed out before, the general tendency of the F_2 distributions was in the direction of the smaller parental breed.

(d) Proportions Between Parts

In order to ascertain if the parental breeds differ in the proportional lengths of the leg and wing bones and in the shape of the skull, the femorotibial, ulno-humeral and cranial indices

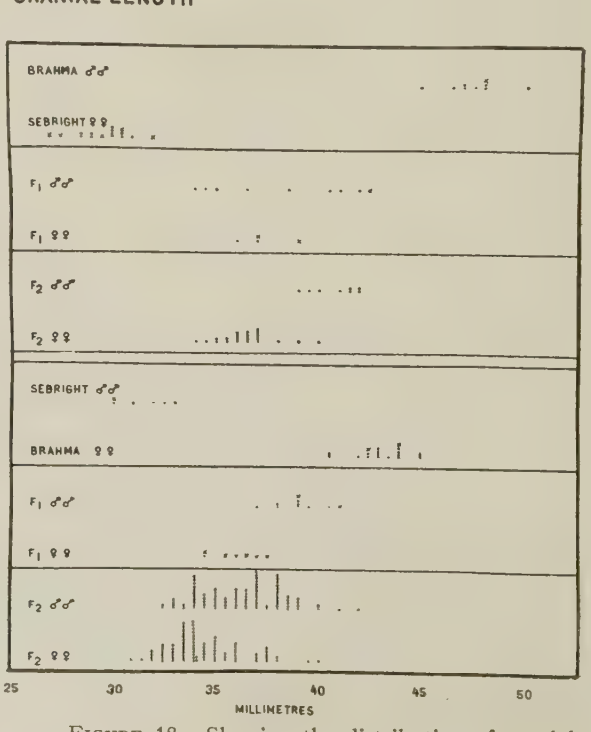

FIGURE 18. Showing the distribution of cranial length in parental, F_1 and F_2 generations.

for these breeds and the F_1 and F_2 generations have been computed. The constants for these indices are given in Table 5. The proportions of the leg bones in the Brahma breed differed slightly from those of the Sebright breed. The difference is barely significant. The F_1 and F_2 mean indices occupy an intermediate position. With regard to the ulno-humeral index, no significant difference existed between the parental breeds.

In the cranial dimensions, a significant difference existed. The Brahma was characterized by a skull which was long and narrow, while that of the

TABLE 5.—MEANS AND VARIATION CONSTANTS OF FEMORO-TIBIAL, ULNO-HUMERAL AND CRANIAL INDICES

Group	Sex	No.	Mean (per cent)	Standard deviation (per cent)	Coefficient of variability (per cent)
			Femoro-tibial index*		
Light Brahma	♂ ♂	9	67.660±0.602	1.806±0.426	2.669±0.629
	♀ ♀	18	69.505±0.156	0.736±0.111	1.059±0.159
Golden Sebright	♂ ♂	6	70.600±0.891	2.182±0.630	3.090±0.892
	♀ ♀	16	71.350±0.382	1.448±0.256	2.029±0.358
F_1 (S×B)	♂ ♂	10	68.784±0.256	0.811±0.181	1.179±0.263
	♀ ♀	7	69.161±0.449	1.188±0.317	1.717±0.458
F_1 (B×S)	♂ ♂	9	69.813±0.491	1.472±0.347	2.108±0.496
	♀ ♀	4	70.205±0.368	0.736±0.260	1.408±0.498
F_2 (S×B) (S×B)	♂ ♂	89	69.863±0.121	1.145±0.086	1.639±0.123
	♀ ♀	83	70.783±0.176	1.609±0.125	2.273±0.176
F_2 (B×S) (B×S)	♂ ♂	8	68.492±0.640	1.812±0.453	2.645±0.661
	♀ ♀	22	69.905±0.340	1.597±0.241	2.284±0.344
			Ulno-humeral index**		
Light Brahma	♂ ♂	9	89.109±0.547	1.642±0.387	1.673±0.394
	♀ ♀	22	97.508±0.292	1.239±0.206	1.271±0.212
Golden Sebright	♂ ♂	6	97.738±0.574	1.406±0.406	1.438±0.415
	♀ ♀	16	95.916±0.474	1.895±0.335	1.975±0.349
F_1 (S×B)	♂ ♂	10	98.243±0.436	1.380±0.308	1.405±0.314
	♀ ♀	7	96.843±0.344	0.912±0.244	0.923±0.247
F_1 (B×S)	♂ ♂	9	98.556±0.388	1.166±0.275	1.183±0.278
	♀ ♀	4	97.670±0.705	1.410±0.499	1.443±0.510
F_2 (S×B) (S×B)	♂ ♂	89	98.999±0.149	1.402±0.105	1.416±0.106
	♀ ♀	83	98.329±0.162	1.476±0.114	1.501±0.116
F_2 (B×S) (B×S)	♂ ♂	8	98.963±0.432	1.223±0.305	1.235±0.306
	♀ ♀	22	97.986±0.314	1.471±0.222	1.501±0.226

*Femoro-tibial index $= \frac{\text{Femur length} \times 100}{\text{Tibia length}}$

**Ulno-humeral index $= \frac{\text{Ulna length} \times 100}{\text{Humerus length}}$

TABLE 5.—MEANS AND VARIATION CONSTANTS OF FEMORO-TIBIAL, ULNO-HUMERAL AND CRANIAL INDICES—*Concluded*

Group	Sex	No.	Mean (per cent)	Standard deviation (per cent)	Coefficient of variability (per cent)
			Cranial index***		
Light Brahma	♂ ♂	9	62.048±0.491	1.474±0.347	2.735±0.644
	♀ ♀	18	62.944±0.289	1.358±0.205	2.157±0.325
Golden Sebright	♂ ♂	6	66.968±0.410	1.004±0.290	1.499±0.433
	♀ ♀	16	67.418±0.383	1.453±0.257	2.153±0.380
F_1 (S×B)	♂ ♂	10	64.380±0.437	1.382±0.509	2.146±0.479
	♀ ♀	7	65.058±0.508	1.344±0.359	2.066±0.552
F_1 (B×S)	♂ ♂	9	65.122±1.031	3.095±0.729	4.752±1.120
	♀ ♀	4	64.437±0.352	0.705±0.249	1.094±0.387
F_2 (S×B) (S×B)	♂ ♂	89	65.457±0.261	2.467±0.185	3.769±0.282
	♀ ♀	83	66.384±0.246	2.246±0.174	3.383±0.262
F_2 (B×S) (B×S)	♂ ♂	8	62.547±0.569	1.611±0.403	2.575±0.644
	♀ ♀	22	65.240±0·553	2·594±0·391	3·976±0·599

***Cranial index $= \frac{\text{Cranial breadth} \times 100}{\text{Cranial length}}$

Golden Sebright was short and broad. The mean indices of the F_1 progenies are intermediate between those of the parental breeds. The F_2 mean indices are also intermediate. Dunn (*7*) observed the effects of inbreeding on the bones of the fowl and found evidence indicating "the segregation of factors affecting the correlation of growth in length and breadth" of the skull. A cross was made between two lines which had differentiated in skull shape through inbreeding and the F_1 was found to be intermediate in shape. Dunn found that the proportions of the cranial dimensions show family differentiation to a more marked degree than do the proportions of the leg bones. It would appear that shape factors exist in the fowl and that differences occur not only between breeds but also between families within breeds.

(e) Coefficients of Correlation

The relationship of the various skeletal dimensions to each other may be determined by the correlation existing between these parts. The coefficients of correlation for the F_2 (S×B) (S×B) males and females are given in Table 6. There is a high degree of relationship between the various measurements which indicates that general factors are largely responsible for the bone dimensions. A high degree of correlation between certain bone measurements in rabbits was found by Castle (*3*). Dunn (*7*), in a group of S.C. White Leghorn hens, found high coefficients of correlation with which the results of this study agree. The coefficients obtained by Wright (*37*) from Dunn's data are given in Table 6. Wright analysed the data obtained by Castle on rabbits and Dunn on fowls to determine

TABLE 6.—COEFFICIENTS OF CORRELATION

Correlations	F_2 (S×B) (S×B) Males (89)	F_2 (S×B) (S×B) Females (83)	Wright Females (276)
	(value of r)	(value of r)	(value of r)
Femur length—tibia length	.995 ± .009	.971 ± .006	.924
Femur length—humerus length	.958 ± .009	.957 ± .009	.875
Femur length—cranial length	.765 ± .045	.770 ± .044	.570
Femur length—cranial breadth	.716 ± .052	.794 ± .040	.526
Humerus length—ulna length	.965 ± .007	.982 ± .004	.940
Humerus length—metatarsus length	.902 ± .020	.932 ± .014	—
Humerus length—cranial length	.722 ± .051	.774 ± .044	.615
Humerus length—cranial breadth	.721 ± .051	.788 ± .041	.576
Cranial length—cranial breadth	.753 ± .046	.768 ± .045	.584

the effect of general, group, and special factors. Wright found in the case of fowls that "the most important factor is general in action, but the head measurements constitute a group with a common factor determining about 20% of their variances. The leg and wing measurements depend upon a common factor, not operative on the head, which determines 4 to 6% of their variances."

In this study the coefficients of correlation between bones of the leg and the wing are very high. The correlations of the leg and wing bones with cranial length and breadth and that between the cranial measurements are significantly lower. These differences support the view that while the size of the various parts of the skeleton are determined by general factors yet to some extent certain parts, such as the cranial dimensions, are influenced by special factors.

(f) Linkage with Qualitative Characters

A number of qualitative characters, whose manner of inheritance is well established, were involved in the Brahma-Sebright cross. Of these characters the following contrasted types could be readily distinguished: silver and gold[4] plumage colour, slow and fast rate of tail feathering, white and yellow shank colour, pea and single comb, and presence or absence of feathers on shank and toes. The bone dimensions of the F_2 individuals grouped into the above classes have been calculated with the view of testing for linkage between the genes for these characters and the genes responsible for size.

Plumage colour and rate of tail feathering are determined by genes located on the sex chromosome. Because of this fact, half of each sex of the F_2 individuals from the (S×B) (S×B) cross should have gold plumage, the other half being silver. The expectation with regard to slow and fast rate of tail feathering is the same. In the reciprocal cross, only the females may be used since all the males are silver and slow, each carrying a dominant gene for these characters on one sex chromosome. Table 7 gives the mean bone measurements for the silver and the "gold," and the fast and the slow classes from the (S×B) (S×B) cross. A total of 89 males was involved.

[4] While gold plumage is brought about by other autosomal genes in combination with the sex-linked allele of the gene for silver, the term gold will be used in the following discussion as a convenient designation of the non-silver group.

TABLE 7.—LINKAGE OF BONE DIMENSIONS AND SEX-LINKED CHARACTERS

Males $F_2(S \times B)$ $(S \times B)$

—	Colour of plumage						Rate of tail feathering					
	Silver (45) Mean (mm.)	Gold (44) Mean (mm.)	Difference (mm.)	D / S.E.d	P	—	Slow (48) Mean (mm.)	Fast (41) Mean (mm.)	Difference (mm.)	D / S.E.d	P	—
Femur	80.078±0.542	79.869±0.753	0.209±0.927	0.225	82.2	S>G	80.583±0.865	79.262±0.810	1.321±1.185	1.115	27.0	S>F
Tibio-tarsus	115.261±1.338	113.795±1.199	1.466±1.796	0.816	41.6	S>G	115.921±1.290	113.158±1.191	2.763±1.756	1.573	11.7	S>F
Tarso-matatarsus	79.238±1.013	78.647±0.884	0.591±1.344	0.440	66.0	S>G	79.640±0.965	78.256±0.914	1.384±1.328	1.042	29.8	S>F
Humerus	73.455±0.807	74.607±0.704	1.152±1.071	1.076	28.2	S<G	73.974±0.790	74.085±0.719	0.111±1.065	0.104	91.6	S<F
Ulna	72.733±0.812	73.608±0.729	0.875±1.091	0.802	42.0	S<G	73.422±0.801	72.865±0.731	0.557±1.084	0.514	60.7	S>F
Cranial length	36.550±0.315	36.170±0.279	0.380±0.421	0.909	36.0	S>G	36.474±0.306	36.232±0.285	0.242±0.418	0.579	56.0	S>F
Cranial breadth	23.711±0.164	23.755±0.155	0.044±0.225	0.195	84.5	S<G	23.682±0.157	23.792±0.162	0.110±0.225	0.488	62.5	S<F

Females $F_2(S \times B)$ $(S \times B)$

	Silver (39)	Gold (43)					Slow (43)	Fast (39)				
Femur	72.852±0.819	68.575±0.653	4.277±1.047	4.085	0.006	S>G	72.529±0.725	68.481±0.788	4.048±1.071	3.779	0.016	S>F
Tibio-tarsus	102.549±1.162	97.226±0.983	5.323±1.522	3.497	0.052	S>G	102.067±1.039	97.211±1.130	4.856±1.535	3.163	0.160	S>F
Tarso-metatarsus	68.167±0.794	64.825±0.638	3.342±1.018	3.282	0.108	S>G	67.941±0.715	64.731±0.719	3.210±1.014	3.165	0.160	S>F
Humerus	67.217±0.705	64.924±0.606	2.293±0.930	2.465	1.36	S>G	67.075±0.620	64.846±0.693	2.229±0.930	2.397	1.600	S>F
Ulna	66.263±0.727	63.756±0.593	2.507±0.938	2.673	0.76	S>G	66.071±0.685	63.686±0.716	2.385±0.990	2.409	1.600	S>F
Cranial length	35.038±0.283	33.942±0.228	1.096±0.363	3.019	0.27	S>G	35.034±0.257	33.833±0.233	1.201±0.346	3.471	0.056	S>F
Cranial breadth	23.109±0.164	22.656±0.119	0.453±0.203	2.227	2.600	S>G	23.075±0.145	22.647±0.137	0.428±0.199	2.150	3.20	S>F

Of this number, 45 had silver plumage and 44 "gold" plumage, while 48 were slow feathering and 41 fast feathering. These ratios agree well with the expectation. It can be seen that there is no indication that the bone dimensions of the males had any association with either of these sex-linked characters. The differences are slight and of no significance statistically. Moreover what differences do exist are in favour of the dominant character for certain bone measurements, and of the recessive character for others.

The 82 females also showed good agreement with the expectation in regard to plumage colour and rate of tail feathering. There were 39 with silver plumage and 43 with "gold" plumage; 43 slow-feathering and 39 fast-feathering. The results show that the silver females were larger than the "gold" females in all dimensions. Likewise the slow-feathering females were larger than the fast-feathering females. Since silver and slow were together in the Brahma parent, the same females, except for a few cases of crossovers, comprised these two groups. The differences in bone dimensions between the silver and the "gold" classes are not large, but are significant. The females from the reciprocal (B×S) (B×S) have not been included in this tabulation because of the small population obtained. The size differences in this group between the silver and the "gold," and the slow and the fast classes were quite evident, but, due to the large standard errors, are not significant. It is evident from these data that a gene associated with sex-linked characters has an influence on the size of females as measured by bone dimensions.

The lack of difference between the contrasted plumage and rate of feathering classes in the males provides some clue as to the nature of the factor involved. This result could be produced by the action of a dominant sex-linked inhibitor of size, closely linked with the genes for "gold" plumage and fast feathering. The silver and the slow classes of males, being heterozygous for these characters and carrying the dominant inhibitor, would, on this hypothesis, be reduced to the same size as the "gold" and the fast classes. The silver and the slow classes of females, lacking the dominant inhibiting gene, would be larger than the "gold" and the fast classes of females.

With regard to the other contrasted characters which are due to autosomal genes, the data given in Table 8 show that there was no tendency for either the W-w pair of genes for shank colour, or the P-p genes for comb type to be associated with size. The segregation for these characters was fairly close to the expectation on a single-factor basis. In no case does the difference in bone size approach a significant level and the direction of the differences varies for the separate bone dimensions. The segregation for leg-feathering and clean legs was in a 15 : 1 ratio. It was not possible to classify the birds according to the degree of leg-feathering caused by the two genes involved. The number of clean-legged birds whose bones were available for study is insufficient to test for linkage between size factors and leg-feathering. A classification of the remaining birds was made on the degree of leg-feathering as follows: heavy, medium, light, tarsal stripe and toe stubs. No significant differences exist in the bone dimensions of these groups.

TABLE 8.—LINKAGE OF BONE DIMENSIONS AND AUTOSOMAL CHARACTERS

—	Sex	Colour of shank: Slate and white (W) (♂♂70, ♀♀61) Mean (mm.)	Colour of shank: Yellow and green (w) (♂♂16, ♀♀20) Mean (mm.)	Colour of shank: Difference (mm.)	Colour of shank: D / S.E.d	Colour of shank: P	Colour of shank: —	Comb form: Pea (♂♂41, ♀♀30) Mean (mm.)	Comb form: Single (♂♂9, ♀♀17) Mean (mm.)	Comb form: Difference (mm.)	Comb form: D / S.E.d	Comb form: P	Comb form: —
Femur	♂♂	79.896±0.662	79.906±1.655	0.010±1.782	0.006	100.0	W<w	80.109±0.855	80.166±1.798	0.057±1.990	0.028	97.8	P<S
	♀♀	70.942±0.780	70.762±0.925	0.180±1.210	0.149	88.1	W>w	72.000±1.133	71.441±1.104	0.559±1.581	0.354	72.3	P>S
Tibio-tarsus	♂♂	114.086±1.134	115.203±2.132	1.117±2.415	0.462	64.3	W<w						
	♀♀	100.043±1.092	100.400±1.298	0.357±1.696	0.210	83.3	W<w						
Tarso-metatarsus	♂♂	78.789±0.735	79.234±1.688	0.445±1.841	0.242	80.9	W<w						
	♀♀	66.660±0.747	66.900±0.864	0.240±1.142	0.210	83.3	W<w						
Humerus	♂♂	74.025±0.593	73.562±1.330	0.463±1.456	0.318	75.8	W>w	74.463±0.677	74.361±1.030	0.102±1.232	0.082	93.4	P>S
	♀♀	66.364±0.698	66.462±0.702	0.098±0.989	0.099	92.0	W<w	67.342±0.879	66.897±0.839	0.445±1.215	0.366	71.4	P>S
Ulna	♂♂	73.136±0.604	73.359±1.365	0.223±1.492	0.149	88.1	W<w						
	♀♀	65.094±0.703	65.475±0.690	0.381±0.985	0.387	69.8	W<w						
Cranial length	♂♂	36.368±0.223	36.000±0.598	0.368±0.638	0.577	56.2	W>w	36.524±0.260	36.166±1.343	0.358±1.361	0.263	77.6	P>S
	♀♀	34.528±0.251	34.537±0.280	0.009±0.376	0.024	98.1	W<w	34.758±0.367	34.838±0.331	0.080±0.494	0.162	87.1	P<S
Cranial breadth	♂♂	23.725±0.123	23.718±0.294	0.007±0.318	0.022	98.2	W>w	23.927±0.120	23.416±0.385	0.511±0.403	1.267	20.8	P>S
	♀♀	22.934±0.127	22.787±0.198	0.147±0.240	0.612	54.0	W>w	23.058±0.934	22.926±0.221	0.132±0.959	0.136	89.2	P>S

DISCUSSION

While the results of this study are considered as the effects of the breeds involved, it must be borne in mind that they might be attributed to the individual characteristics of the birds used as parents. The breeds of domestic fowl cannot be considered as being homogeneous with respect to size. The racial or strain means may be used as a description of the parental birds only when those individuals do not deviate widely from the others of the same group. Where the technique, necessary in crossing two breeds widely different in size, limits the number of parental matings, the characteristics of the resulting progenies must be judged from this viewpoint. The birds used as parents in the production of the subsequent generations are indicated by an "x" in the distributions shown in Figures 17 and 18. The Brahma male used did not differ in bone dimensions from the other Brahma males measured except for a slightly greater length of tibio-tarsus and tarso-metatarsus bones. The Sebright male was smaller than the other Sebright males in the length of the leg and wing bones, but not in the cranial dimensions. The Brahma females used occupy an intermediate position in the distributions. Sebright females including the largest and smallest birds were used as parents.

A consideration of the results relative to the bone dimensions in the F_1 generation of the reciprocal crosses between the above birds, and in the subsequent F_2 progenies leads to the following: (1) the F_1 hybrids, with the exception of the females from the (S×B) cross, were slightly smaller than intermediate between the means of the parental strains; (2) the above exceptional females were very much smaller than intermediate in all measurements except cranial length and cranial breadth; (3) the coefficients of intercorrelation of cranial measurements and the length of the leg and the wing bones are somewhat lower than the intracorrelation of the bones of the leg and the wing; (4) linkage studies of the F_2 show that females carrying the sex-linked gene for "gold" plumage were smaller in all measurements than females carrying the allelic gene for silver; (5) there was no difference in bone dimensions between the "gold" and the silver males of the F_2 (S×B) (S×B) cross; (6) the explanation of the difference between the males and the females in the linkage relations of colour and size may lie in the existence of a dominant sex-linked inhibitor of size which reduces the size of the silver males to that of the "gold" males; (7) the differences displayed by cranial length and cranial breadth of the F_1 progenies and in the coefficients of correlation indicate that these parts are to some extent inherited independently. In effect the special factors which act on the cranial dimensions counteract the action of the sex-linked inhibitor.

On the assumption that the multiple-factor hypothesis adequately explains the inheritance of size in the domestic fowl, some attempts have been made in studies of body weight to estimate the number of genes involved. This estimation has been based on the range and characteristics of the F_2 frequency distribution curve and the type of progeny produced by selected F_2 individuals. The reappearance of the parental types within a relatively small F_2 population and the results from later generations has in two cases led to the opinion that a small number of genes govern the inheritance of size. Punnett and Bailey (*27*) in the Hamburgh-Sebright

Bantam cross found that the results might be explained by the action of four independent genes. Waters (*36*) believed that two pairs of genes, with a cumulative effect, control body weight in the Brahma-Leghorn cross. On the other hand, Jull and Quinn (*15*) are of the opinion that many genes are probably involved. In this study there were found in an F_2 population of 202 individuals small males and females within the range of the parental breeds. The evidence with regard to the number of genes responsible for size, as judged by skeletal dimensions, is not more critical than that of previous studies on body weight. The difficulty in all cases would appear to lie in the variability of the birds used as parents. The solution of this problem will be brought nearer when uniform strains, produced by inbreeding, are available for this type of study.

On the other hand, some information as to the nature of the genes involved may be obtained from crosses between existing breeds. It has been generally supposed that the genes for quantitative characters lack dominance. This assumption, with the other features of the multiple-factor hypothesis, has been deemed necessary to account for the results when two species, differing in some quantitative character, are crossed. Several workers have pointed out that the non-dominance of size genes as a theory is not in accordance with the accepted explanation of hybrid vigor in which the genes are considered as being dominant. It is hardly consistent to expect that such similar phenomena should result from two entirely different types of gene-behaviour. Turner (*33*) and Goodale (*10*) have drawn attention to this inconsistency and point out that in many cases the results of studies on quantitative characters are not completely explained by the multiple-factor theory with the operation of non-dominant genes. On the basis that species are quite probably heterozygous for size genes, Goodale believes that the variable results obtained, such as cases in which the F_1 does not occupy an intermediate position between the parents, are due to the action of dominant genes which exist in varying proportions to the recessive genes in the individuals which are crossed. If an individual with a number of size genes in the heterozygous condition is mated to an individual which carries the corresponding recessives the offspring will, on the average, be intermediate in size. Such a result can be explained by either dominant or non-dominant genes. But those cases in which the offspring approach either parental mean cannot be explained by non-dominant genes unless the parents used vary widely from the racial mean. Goodale is of the opinion that both dominant and non-dominant genes may be involved in size inheritance. Rasmusson (*29*) developed an "interaction hypothesis" to explain certain results in size inheritance studies in plants. The genes responsible for size are described as being dominant, and are not expressed in an additive form but rather in a geometrical series. Lindstrom (*20*), in a study of fruit size in the tomato, has found evidence that a dominant gene for small size is present in the wild-type plant.

Previous studies concerning the inheritance of body weight in the domestic fowl have not produced much evidence regarding the nature of the genes for size. In no case has it been possible to isolate a gene or genes which have a specific effect. The evidence with regard to dominance is rather conflicting. Punnett and Bailey (*27*) and May (*22*) found that the

F_1 generation was larger than intermediate in size. Waters (*36*) and Axelsson (*1*) obtained F_1 progenies intermediate in size, while Jull and Quinn (*15*) found that the F_1 progeny approached the mean weight of the small parents. The results of this study agree with the observations of Jull and Quinn. The F_1 progeny, particularly from the Sebright-Brahma cross, were smaller than intermediate in the size of the bones of the appendicular skeleton. In all cases there was considerable variability in the F_1 progeny, so the results cannot be considered as conclusive on this point.

There is, however, some evidence which indicates that the separate parts of the body may be influenced by special genes. Kopec (*16*), in the Leghorn-Orpington cross, observed the differences in the mode of inheritance of the separate dimensions and indices in the two sexes of the F_1 progeny, and between the F_1 ex Leghorn females and the reciprocal F_1 ex Orpington females. In a study of the effects of inbreeding, Dunn (*7*) found that "the most striking differences between the families appeared in the shape of the cranium." Hutt (*14*) found that the tarso-metatarsus bone exhibited extreme variability and sex dimorphism and expressed the opinion that special factors exist which affect only certain regions and certain individual bones. The study of the skeletal dimensions of the F_1 and F_2 progenies from crosses between the Brahma and Golden Sebright Bantam breeds gives further evidence that some parts of the skeleton are influenced by special factors apart from general factors. This view is supported by the fact that the cranial dimensions were, in the case of the F_1 (S×B) females, a larger percentage of the parental difference than the other bone measurements. Furthermore, somewhat lower coefficients of correlation were found in those cases in which cranial dimensions were involved. The cranial dimensions were also relatively less variable than the other parts of the skeleton. It would appear that special factors are influencing the cranial dimensions which do not affect the bones of the appendicular skeleton.

The data of special interest in this study relate to the indication that a sex-linked factor is associated with size. The wide difference in size which was found between the F_1 female offspring from the reciprocal crosses provided the first evidence of this relationship. Since the F_2 population showed normal segregation for the sex-linked characters, silver-gold plumage colour and slow-fast rate of tail feathering, these classes could be compared with respect to bone dimensions. As pointed out above the "gold" and the fast classes of females were significantly smaller than the silver and the slow classes. In the case of the males, however, no difference existed between the contrasted classes. Regarding the nature of the sex-linked factor involved, the following explanation is suggested. The difference in size might be brought about by a dominant sex-linked inhibitor of size. On this basis, a lack of difference in bone dimensions between the silver and the "gold" males would be expected because of the dominant action of the gene or genes in reducing the size of the silver males to that of the "golds." In connection with this explanation, it should be observed that the bone dimensions of the F_1 (S×B) males are considerably greater than those of the F_2 males. Since the F_1 males and half the F_2 males, the silvers, would be heterozygous, and the F_2 "gold" males homozygous for the inhibitor, the bone dimensions of the F_1 and F_2 males would be expected

to be more nearly equal. In view of the fact that the sex dimorphism of the F_2 population was approximately normal while that of the F_1 was greater than normal, it is evident that the F_1 males were large. It is possible that insufficient F_1 males were measured to give a normal distribution. It was seen that the reciprocal F_2 (B×S) (B×S) generation had a larger than normal sex dimorphism and that the males of this group were, on the average, larger than intermediate. This result can hardly be taken as additional evidence, since the numbers are small, but is consistent with the explanation given. In this group, half of the males would lack the sex-linked inhibitor, and consequently the averages of the bone dimensions should be larger than those of the reciprocal males.

The effect of the sex-linked inhibitor is not apparent on the cranial dimensions of the F_1 females but is seen in the F_2 linkage relations of these measurements. It would seem that autosomal factors are present which in effect counteract the reduction in size caused by the sex-linked inhibitor. The effect of these factors is seen in the F_1 (S×B) females, but not in the F_2 females, since in the latter group segregation would take place, the factors being distributed at random to both the silver and the gold classes. Since only the females show this difference in cranial dimensions, the special factors, if such bring about this effect, must be sex-limited, their expression being conditioned by the presence of the female sex hormone.

Hays (*13*), and more recently Warren (*35*), have shown that one of the factors for early sexual maturity is sex-linked. In view of the fact that the larger breeds of fowl are generally slower in reaching sexual maturity than the smaller breeds, the possibility exists that the sex-linked factor influencing size of bone dimensions is associated with the gene E, for early maturity. The two phenotypic expressions may be the result of the same set of genetic factors.

The skeletal dimensions of the fowl are apparently determined by a number of genes whose action is of a general nature. The data of this study indicate that the dimensions of the skull are partly determined by other special factors. One factor of a general nature is located on the sex chromosome of the Golden Sebright Bantam and has a dominant inhibiting effect on the size of the appendicular skeleton and of the cranial dimensions. Although this effect is attributed to the action of a dominant sex-linked gene, it is quite possible that more genes than one are involved. It is obvious that whatever the nature of the sex-linked inhibitor may be, the final result is determined by the interaction of this factor with the whole gene-complex responsible for the size of the skeletal dimensions. The present size of the Light Brahma and the Golden Sebright Bantam breeds represents the result of selective breeding in opposite directions from the size of the Jungle fowl. The suggestion that the small size of the Golden Sebright Bantam is in part due to the action of a dominant sex-linked inhibitor agrees with the practical experience that unless constant selection for small size is practised the breed tends to increase in size.

SUMMARY

1. The bone dimensions of the appendicular skeletons and skulls of parental, F_1 and F_2 generations from reciprocal crosses of Light Brahmas and Golden Sebright Bantams were measured and analysed statistically.

2. The F_1 and F_2 progenies were, on the average, slightly smaller than intermediate between the parents.

3. The F_1 females from the reciprocal crosses displayed wide differences in the length of the bones of the leg and wing.

4. The variability in bone dimensions was considerably less than that in body weight. The coefficients of variability in the F_2 were slightly greater than those in the F_1.

5. In the proportions of the parts of the skeleton, the Brahma and Sebright Bantam breeds were found to differ significantly in shape of skull.

6. The coefficients of correlation between all parts of the skeleton were high. Slightly lower values were obtained in those cases involving cranial measurements.

7. Linkage was found to exist between factors for size and two sex-linked characters, plumage colour and rate of tail feathering. It is concluded that a sex-linked factor is present in this cross which brings about a reduction in size of the skeletal dimensions.

8. The evidence relating to cranial dimensions indicates that the skull is influenced by special factors.

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Résumé

La transmission héréditaire des dimensions squelettiques dans les volailles domestiques. A. J. G. Maw, Collège Macdonald, Québec.

Les dimensions des os des squelettes appendiculaires et des crânes des générations, F_1 et F_2, issues de croisements réciproques de Brahmas légers et de Bantams Golden Sebright, ont été mesurées et analysées statistiquement. Les progénitures F_1 et F_2 étaient en moyenne un peu plus petites que l'intermédiaire entre les parents. Les femelles F_1 issues des croisements réciproques présentaient des différences considérables dans la longueur des os des pattes et de l'aile. La variabilité dans les dimensions des os était bien inférieure à celle du poids du corps. Les coefficients de la variabilité dans F_2 étaient un peu plus grands que dans F_1. Dans les proportions des parties du squelette, les races Brahma et Sebright Bantam différaient beaucoup l'une de l'autre au point de vue de la forme du crâne. Les coefficients de corrélation entre toutes les parties du squelette étaient élevés. Des chiffres un peu plus faibles ont été obtenus dans les cas qui comportaient des mesurements du crâne. On a trouvé qu'il existait une relation entre les facteurs de la dimension et deux caractères reliés au sexe, la couleur du plumage et la densité du plumage de la queue. L'auteur conclut qu'un facteur relié au sexe est présent dans ce croisement et cause une réduction dans la grandeur des dimensions squelettiques. Les preuves recueillies au sujet des dimensions crâniales indiquent que le crâne est influencé par des facteurs spéciaux.